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International Student Mobility and Social Inclusion in Cities: A Case-Based Evaluation within the Erasmus+ Framework

Hatice Gamze ÖRS

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ABSTRACT

This study aims to examine the impact of international student mobility on social inclusion in cities within the framework of the Erasmus+ program. The rapid transformation of the social structure of cities due to global migration increases the importance of social inclusion policies and necessitates the integration of individuals with different cultural backgrounds into urban life [1]. The Erasmus+ program enables young people to study and do internships in different cities, transforming not only the individual but also society at large [2]. This study adopted a qualitative, autoethnographic approach, drawing on the author's Erasmus experiences in Poland and Finland and her institutional observations as an Erasmus office manager in Turkey [3]. The findings suggest that student mobility enhances intercultural understanding, promotes social inclusion and increases a sense of belonging. However, students may experience challenges such as accommodation, language barriers and access to public services, suggesting that the principle of social inclusion is not fully realized in practice [4]. Although universities and local governments support this process through orientation programs and social events, there are gaps between practice and policy (Council of Europe, 2018). In conclusion, it is emphasized that international students should not be considered as temporary guests, but as actors contributing to the social structure of cities, and that it is essential to strengthen social inclusion through more participatory and youth-friendly policies at the local level. While Erasmus+ is celebrated for enabling international experiences and fostering intercultural competence, recent research suggests a gap between its social inclusion objectives and practical implementation. As Cairns notes, "there is an imbalance between programmatic goals, which explicitly reference social inclusion, and what actually happens within the undergraduate exchange programme" [5].

Key words: International Student Mobility, Social Inclusion, Erasmus+, City Participation

Introduction

In the 21st century, globalization and increased migration movements are transforming cities not only economically and physically but also socially. This transformation is manifested in increasing cultural diversity and multicultural forms of interaction in urban life. For cities to become sustainable, livable and equitable places, the principle of social inclusion is not only an ideal but also a necessity [1]. Social inclusion aims to promote the equal, dignified and active participation of individuals - especially migrants, refugees and international students - in urban life [6].

In this context, international student mobility offers a unique ground for examining social inclusion processes in cities. The Erasmus+ program, supported by the European Union, allows students to study or do internships in different countries, strengthening cultural interaction between individuals and social ties between cities. Erasmus+ participants become part of not only academic communities but also social life, public spaces and everyday interactions in the cities they visit [6].

However, the contribution of this mobility experience to social inclusion is related to the conditions of not only being present but also being able to participate effectively. Barriers in daily life such as housing, language, transportation, and access to public services directly affect the relationship that individuals establish with the city [7]. Therefore, while international student mobility has the potential for social inclusion, how this potential is met and managed at the city scale should be critically evaluated.

The aim of this study is to analyze the impact of international student mobility under the Erasmus+ program on social inclusion in cities based on personal experience and institutional observation. The author's personal experiences as an Erasmus student in Poland and Finland and her institutional observations during her time working in the Erasmus office of a university in Turkey constitute the main data source of the study. Through this dual perspective, the concept of social inclusion is opened to discussion at both individual and institutional levels. While many institutions advocate for equity, diversity, and inclusion (EDI), international students are often overlooked as an equity-seeking group, despite their unique vulnerabilities. Tavares (2024) stresses that "international students felt excluded and othered in the community," even at universities that claim strong EDI commitments [8]. nternational student mobility (ISM), long perceived as a symbol of openness and equal opportunity, is in fact marked by persistent social inequalities. According to Lomer et al., "access and participation is variable across underprivileged groups, experiences and engagement varies, as do outcomes" [9]. Cities play a pivotal role in providing opportunities for upward mobility, as they serve as dense environments where economic, educational, and social resources are concentrated [10].

Methodology

This study is structured within the qualitative research paradigm by adopting an experience-based approach. Autoethnography was preferred as the main method of research. Autoethnography is a qualitative research method that allows the researcher to analyze social, cultural and institutional structures based on their personal experiences [3]. This approach allowed the researcher to examine both her participation in the individual mobility process as an Erasmus+ student and his/her observations while working as an administrative staff in the Erasmus office of a university on an academic basis. In addition to personal experiences, this study incorporates institutional observations, aligning with Cairns' meso-level approach, which focuses on those managing Erasmus programmes to uncover deeper structural challenges in inclusion [5].

The data source of the study consists of the researcher's study mobility in Poland in 2016, her internship experience in Finland in 2017 and her field experience as an Erasmus office manager in Turkey since 2019. These experiences were analyzed under the themes of social inclusion, belonging, connection to the city, intercultural interaction and institutional support mechanisms. The data consists of qualitative content such as written notes, personal reflections, diaries and organizational reports.

The main advantage of the autoethnographic approach is that it provides in-depth insights, as the researcher is involved in the process as both observer and participant. However, the method also has limitations. First of all, the generalizability of the findings is limited; the study is limited to a specific context and the subjective experiences of the researcher. However, these limitations do not overshadow the method's power of in-depth analysis. Autoethnography is considered a powerful tool in the social sciences for linking individual experience with theoretical debates [11]. This paper's methodological approach aligns with the argument that "the experiences of international students must be examined beyond policy frameworks and from emic, subjective, and lived perspectives" [8]. The study adopts a broad understanding of social inequalities, defined not as mere differences but as "experiences of harm or privilege as a result of ascriptive identity or socio-economic background," which shape access, participation and outcomes in ISM [**9**]. In line with Michelangeli and Türk (2021), this paper considers the urban context as a critical factor in human capital formation, alongside family and educational inputs [10]. The Covid-19 pandemic revealed stark environmental inequalities in urban settings. As Wilson et al. observe, "walkability matters more than regional accessibility for building social connections,"

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especially during lockdowns when mobility was constrained [13].

Main Results and Discussion

In this section, the findings that emerged from the researcher's personal experiences during the Erasmus+ student mobility process as well as her observations on institutional practices are discussed within the framework of themes. The findings categorize the reflections of social inclusion in urban life under four main headings: intercultural interaction, sense of belonging, challenges faced, and the impact of institutional support.

1. Intercultural Interaction and Social Inclusion

Students abroad as part of Erasmus+ build multifaceted relationships not only with the academic environment, but also with the city, everyday life and the local community. Experiences in Poland and Finland show that students develop higher levels of empathy and strengthen intercultural communication skills when they interact with different cultures. As students participate in volunteer activities, student clubs or social programs, their language skills improve and their sense of belonging to the city increases [7].

2. A Sense of Belonging and Connection to the City

International students' sense of belonging to the city they live in stems not only from being physically present there, but also from being a part of active social life. Participatory city policies facilitate students' social bonding processes and increase social cohesion [6]. The author's own experience shows that students develop this sense of belonging the most when they have direct contact with the local community. The study supports the idea that local green space proximity—rather than general regional availability—is key to enabling not only physical activity but also social cohesion and mental resilience [13]. This is particularly relevant to students and newcomers who rely on walkable, safe public spaces to integrate into urban life.

3. Challenges

The main problems encountered during student mobility include finding accommodation, language barriers, adapting to the transportation system, and access to health services [4]. These problems may cause interruptions in students' relationships with the city and negatively affect the level of social inclusion. Bureaucratic barriers in accessing public services in Finland and difficulties in finding a dormitory in Poland revealed that the practice of inclusion varies significantly at the local level.

4. Institutional Support Mechanisms

Orientation programs, language courses and social activities offered by universities contribute significantly to the integration process of students. However, it has been observed that these supports often remain standard and superficial; they are not customized according to the individual needs of students [6]. The fact that municipalities are often not involved in this process leads to social inclusion being university-based only. However, participatory social programs developed at the city level can enable students to participate more actively in urban life [2]. The findings align with research showing that students who move to resource-rich university cities significantly increase their chances of upward social mobility compared to those who remain in less developed hometowns [10].

Conclusion

This study examines the potential of international student mobility to contribute to social inclusion in cities, based on personal and institutional experiences with the Erasmus+ program. The findings show that Erasmus+ mobility increases intercultural interaction in cities and students become part of social life and develop belonging. However, students also face various challenges; limitations in areas such as housing, language and access to public services hinder social inclusion. This situation reveals that inter-

national programs such as Erasmus+ need to be supported by effective policies not only at the individual but also at the urban level. Without stronger municipal engagement and tailored financial mechanisms, the Erasmus+ programme risks favoring students who are already socially and economically advantaged. As Cairns explains, “mobility exchange platforms fall prey to a ‘Matthew Effect’ in supporting the career development of students already rich in social and economic capital” [5]. Orientation programs and social activities offered by universities facilitate the integration process but are often not individualized enough. The lack of active participation of local governments in social inclusion processes also weakens this process. Therefore, it is of great importance to develop holistic support mechanisms where universities and municipalities work in coordination and focus on the cultural and social needs of [6;2]. The study supports existing literature suggesting that “despite multicultural environments, universities often lack meaningful institution-led efforts to foster intercultural interaction,” which leads to feelings of social isolation among international students [8]. The findings align with Wilson et al. (2024), who showed that “mental health was directly influenced by social cohesion during the early phase of the pandemic,” and that green space use significantly improved social connectedness [13].
It should also be emphasized that students participating in the Erasmus+ program should be considered not only as temporary guests but also as individuals who contribute to the social structure of cities. In this context, participatory city policies that hear the voices of young people and are sensitive to their needs will ensure the sustainability of social inclusion. Future studies can provide a more comprehensive evaluation by comparing institutional practices in different cities. While many national higher education systems promote access and equality, “few apply these principles to international student mobility,” leaving underrepresented groups at a disadvantage despite inclusive rhetoric [9].

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Youth-Led Urban Agriculture: From Soil to Market for a Resilient Future

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ABSTRACT

Urban agriculture offers innovative opportunities for youth empowerment and increased urban resilience. This paper proposes a youth-led model designed to engage young people actively in sustainable food production. The model includes practices such as school-based greenhouses, neighborhood gardens, and youth-operated local markets. These activities contribute not only to ecological awareness but also to entrepreneurship and social inclusion. The initiative highlights the importance of youth participation in local food systems, particularly in the face of climate challenges and food insecurity.

By integrating community engagement with environmental action, the model aims to create a circular ecosystem in which young people are both producers and agents of change. Designed for implementation in collaboration with municipalities, youth NGOs, and educational institutions, the model enhances adaptability to diverse urban contexts. It seeks to nurture self-sufficiency, responsibility, and collective belonging among the new generation. This is not merely a project—it is a platform that enables young people to take root in their communities while contributing to global sustainability goals. This is not just my idea; it is a seed that will grow in your hands.

Keywords: Youth empowerment, Urban agriculture, Sustainability, Local food systems, Social entrepreneurship

Introduction

According to the OECD's sustainability indicators, development requires addressing economic, social, and environmental dimensions simultaneously [1]. In this context, many countries have adopted multidimensional strategies that include promoting agriculture without chemical inputs, reducing carbon emissions, and supporting the education and economic participation of women and youth. Through youth and agricultural policies, local development has become one of the primary goals of sustainable urban planning.

As of 2022, more than 20 countries have incorporated youth participation in agriculture into their national strategies. For example, Germany promotes agriculture-based education in schools through the "Grüne Berufe" (Green Professions) program; the Netherlands offers funding opportunities for urban gardening and young farmers [2]. In Asia, South Korea's "Return of Youth to Agriculture" initiative supports reintegration into rural areas, while Japan positions youth as carriers of agricultural heritage [3]. In Africa, Kenya's "Ajira Youth Agripreneurs" program highlights youth leadership in digital agriculture, whereas Nigeria provides state-supported agricultural loans and consultancy services to young farmers [4]. In the Americas, the USA's 4-H Youth Development Program engages over 6 million youth in agricultural learning processes, while Brazil's "Escola Ativa" program integrates agriculture into rural education [5,6]. In Turkey, over 40,000 young people have benefited from the Ministry of Agriculture and Forestry's Young Farmer Program, and school garden agriculture projects have been implemented in more than 300 schools across 81 provinces [7].

Agriculture should be redefined for youth not only as a livelihood but also as a process of productivity, responsibility, and social contribution. Zimmerman's Empowerment Theory (1995) emphasizes the importance of opportunities that enable individuals to actively participate in decision-making processes and develop skills that allow meaningful contributions to society [8]. In this regard, agriculture can provide a space for both personal development and social participation.

On the other hand, Kolb's Experiential Learning Theory (1984) argues that the most effective form of learning occurs through direct experience [9]. Actively participating in the agricultural cycle—from seed to harvest—activates not only cognitive but also affective and behavioral learning domains. This process supports youth in connecting with nature and internalizing fundamental values such as patience, labor, and sustainability.

This study aims to encourage primary and secondary school students' participation in agricultural activities, the development of marketing strategies for their own products, and integration into local economies. The long-term structure of the model includes supportive elements such as school greenhouses, neighborhood gardens, and local markets operated by youth. The goal within this scope is to empower young people not only as consumers but also as producers, entrepreneurs, and active members of society.

The model is inspired not only by global practices but also by Turkey's historical experience with the Village Institutes. These institutes, by integrating agriculture, production, and education, provided a valuable legacy aimed at reconnecting younger generations with nature and society through sustainability-focused learning. A study examining theses on Village Institutes in Turkey has comparatively addressed the educational philosophy of these institutions alongside the spatial and structural constraints of today's educational institutions [10].

The purpose of this study is to go beyond these spatial limitations and establish a collaborative partnership between farmers actively working in today's agricultural fields and teachers and students within the education system. Thus, the aim is to develop a sustainable model that benefits both parties and to foster social responsibility in students not only through theoretical but also practical experience via applied agriculture.

Theoretical Framework

Today, it is widely accepted that organizations become sustainable not only through their internal dynamics but also through their multidimensional relationships with their environments. At this point, Ludwig von Bertalanffy's general systems theory [11] emphasizes that social organizations, such as schools, must maintain continuous and reciprocal interaction with their environment, much like living organisms. Just as individuals in open systems require physical inputs essential for survival, organizations are expected to receive information, resources, and support from their environment and process these inputs into outputs.

In line with Bertalanffy's systems approach, Parsons (1970) proposed that four fundamental functions must be fulfilled for organizational sustainability: adaptation (to the environment), goal attainment, integration, and pattern maintenance (AGIL model) [12]. The youth-based urban agriculture model redefines these functions within the school context. Students' resource-finding processes correspond to adaptation; planning from product selection to sales aligns with goal attainment; task distribution and cooperation within the team reflect integration; and belongingness and sustainability fulfill the pattern maintenance function. Built upon this theoretical foundation, the "Youth-Led Urban Agriculture" model is designed as an alternative organizational form that adapts to contemporary environmental and organizational dynamics. In this model, students are expected to independently determine how to access the resources needed for the lands where they will cultivate. Throughout the decision-making process—from selecting the crops to improving soil fertility, and producing or sourcing seeds—students are encouraged to operate based on their competencies in environmental analysis, information acquisition, and problem-solving. Subsequently, production, harvesting, and marketing of products through various digital channels are envisioned as a modern "Village Institute" model suitable for our era.

This model encompasses not only physical production processes but also cognitive and social processes such as accessing information, decision-making, collaboration, and value creation. At this point, the relationship between the organization and its environment can be explained by Resource Dependence Theory. Pfeffer and Salancik (1978) argue that organizations must strategically manage their access to the material (information, seeds, inputs) and institutional (legitimacy, culture, sustainability) resources needed for their sustainability [13]. In this context, the school transforms not merely into an educational institution but also into an organizational actor that analyzes resources, identifies needs, and ensures its own sustainability [14].

Regarding institutionalization, Selznick (1996) and Schein (1993) note that the extent to which organizations internalize norms and values from the external environment determines their organizational culture and legitimacy [15; 16; 17]. In this model, the school's sustainable production practice gradually becomes part of the organizational culture, and student behaviors are shaped by this culture.

At the center of the model is not only the organizational structure but also individual participation. Zimmerman's Empowerment Theory (1995) emphasizes the importance of structures that enhance individuals' active participation in decision-making processes, self-efficacy acquisition, and levels of social contribution [8]. Students participating in agricultural processes take responsibility not only in physical production but also in planning, logistics, sales, and leadership roles, thus gaining micro-organizational experience.

The combination of this micro-level participation with learning can be explained by Kolb's Experiential Learning Theory (1984). According to Kolb, individuals achieve deep learning only through direct lived experience [9]. Young people involved in every stage—from seeding to harvesting, and from marketing to evaluation—experience, analyze, and internalize learning by restructuring in accordance with the cyclical learning model. Looking at the system as a whole, this structure approaches Peter Senge's (1990) "Learning Organization" model, differing from classic school structures. In the school, students, teachers, and administrators are positioned as units that produce, share knowledge, and sustain the development of the system. This enables the school to function not only as an educational institution but also as a dynamic and learning organization that generates social innovation [18].

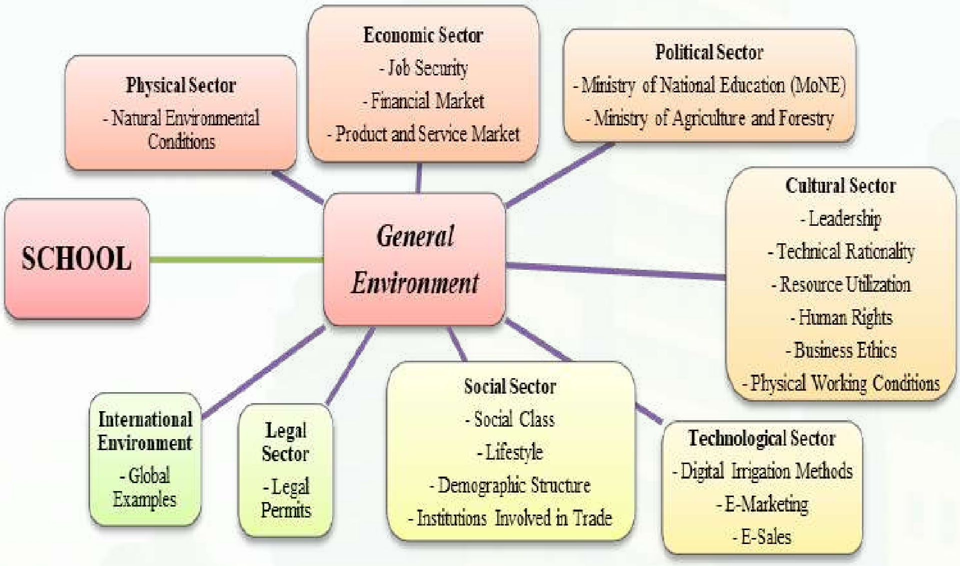

Figure 1. Interaction of the School-Based Production Model with the General Environment: An Open Systems Approach

The core components of this theoretical framework are visualized in Figure 1 according to the open systems approach; subsequently, Table 1 systematically summarizes the conceptual functions of each theory alongside their corresponding roles within the school environment. This structure concretizes the practical application of the theoretical foundation and supports the holistic nature of the model.

Table 1. Theoretical Foundations and Practical Applications of the Youth-Based Urban Agriculture Model

Theory / Theorist	Core Concept / Function	Corresponding Role in the Model (School Environment)
Ludwig von Bertalanffy – General Systems Theory (1968)	Open system; continuous input-output interaction with the environment	The school's continuous interaction with nature, society, and technology; receiving information, seeds, and support from the environment and returning products and impact
Talcott Parsons – AGIL Model (1971)	Adaptation, Goal Attainment, Integration, Latency	Students' resource acquisition (A), goal setting (G), team cohesion (I), value creation (L); functioning of the school as a micro-organization
Pfeffer & Salancik – Resource Dependence Theory (1978)	Dependence on material and institutional resources	Students' access to knowledge, soil, and seeds (material); school's production of legitimacy and sustainability (institutional)
Zimmerman – Empowerment Theory (1995)	Self-efficacy, decision-making power, participation	Students' active roles in production, sales, and decision-making processes; experience of micro-leadership

Kolb – Experiential Learning Theory (1984)	Learning cycle through experience: Concrete Experience → Reflective Observation → Abstract Conceptualization → Active Experimentation	Students' planning, applying, analyzing, and improving throughout the seed-to-product process
Senge – Learning Organization (1990)	Systems thinking, self-organization, continuous learning	School divided into learning units rather than fixed roles; student teams showing continuous development
Selznick & Schein – Institutionalization Approach	Internalization of shared values, culture formation	Agricultural activities becoming part of the school culture; development of belonging, responsibility, and community awareness

As seen in the table, the youth-based urban agriculture model not only offers a production-oriented structure but is also organized as a system where students are positioned as organizational actors who experience key functions such as resource management, leadership, value creation, and environmental interaction. In this context, the model applies the abstract principles of organizational theories to the school environment, providing a holistic framework that enables both individual empowerment and collective learning.

Main Findings

This study does not rely on empirical (experimental) research; rather, it proposes a conceptual model inspired by Turkey's national experiences and global urban agriculture practices led by youth. The primary aim of the model is to actively involve young people in production, decision-making, and social contribution processes through collaborations established among schools, local governments, and civil society organizations.

When evaluated in the context of Turkey, the Ministry of Agriculture and Forestry's Young Farmer Program benefiting more than 40,000 youth and the implementation of school garden agriculture projects in over 300 schools across 81 provinces provide a strong foundational ground for youth participation in agriculture [19, 20]. Although most of these existing initiatives are limited-time activities or structures focused solely on agricultural production, the proposed model aims to elevate these efforts to a more inclusive, sustainable, and participatory level.

The model proposes a holistic structure in which young people assume roles as producers, decision-makers, and marketers. Its main components can be summarized as follows:

School-Based Greenhouses and Gardens: Agricultural activities are intended to be integrated into the curriculum not only through science or biology classes but also through courses on values education, citizenship, and economics, adopting agriculture as an interdisciplinary learning field.

Youth-Managed Community Gardens: Transforming idle urban spaces into collective production areas that support teamwork and ecological responsibility, thereby encouraging young people to develop a shared responsibility in public spaces.

Young Farmer Markets: Enabling students to sell their own products in local markets to enhance entrepreneurship, communication, and financial literacy skills, thereby increasing their level of economic participation.

Education and Mentorship: Establishing collaborations with local producers, agricultural engineers, and volunteer experts to provide students with field-based knowledge and professional guidance throughout the practical processes.

Digital Documentation and Community Sharing: Encouraging students to document the production process using digital tools and share it on social media and local platforms, thereby raising social awareness and leading the spread of similar practices in other schools.

This structure is evaluated as contributing not only to local food systems but also to youth-focused social entrepreneurship [21]. Although developed based on Turkey's unique conditions, the model's flexibility and multi-layered structure offer a scalable framework that can be easily adapted to different geographies and educational systems. The ultimate goal is to reconnect youth with nature, empower them through production, and facilitate social participation to contribute to long-term sustainability.
The comparative table below shows the key differences between the school-based agricultural projects currently implemented in Turkey and the proposed youth-focused model. This structure clearly reveals the model's holistic nature in pedagogical, economic, and participatory dimensions.

Table 2. Comparison Between Existing School-Based Agriculture Programs and the Proposed Youth-Focused Model

Existing School Programs	**Proposed Model**
Focused on gardening and basic planting activities.	Covers a full-cycle process including production, marketing, and circular sustainability.
Students are observers or passive participants.	Students take on roles as producers, marketers, and decision-makers.
No economic or entrepreneurial dimension.	Emphasizes entrepreneurship skills and economic participation.
One-time or seasonal activities.	Integrated into long-term educational processes.
Teacher-centered.	Offers a youth-focused, participatory learning model.
Digital tools are either absent or very limited.	Includes digital documentation, media sharing, and community interaction.

The comparative analysis presented in Table 2 clearly reveals the limitations of current practices and the innovations introduced by the proposed model to overcome these constraints. To visually express how the core components of the model complement each other within a circular structure, Figure 2 below summarizes the multilayered experiential learning process of youth, spanning from production to marketing, digital representation, and empowerment.

Figure 2. Youth-Led Circular Agriculture Model

This circular diagram illustrates the interconnected structure of components such as production, marketing, storytelling, and empowerment. The model aims to enhance youth participation, skill development, and social impact.

Conclusion

This study conceptually addresses a school-based urban agriculture model developed under youth leadership, aiming to provide a holistic response to interconnected global challenges such as food insecurity, youth unemployment, disconnection from the environment, and declining social participation. Although urban agriculture initiatives have increased in recent years, many of these efforts remain limited to local gardening and fail to achieve sufficient integration at pedagogical, economic, and institutional levels.

The proposed model combines Kolb's Experiential Learning Theory (1984) and Zimmerman's Empowerment Theory (1995) to support the transformation of youth from passive participants to active decision-makers. Unlike traditional school garden projects, this approach places entrepreneurship, digital storytelling, and social visibility at the center of the learning process. These components are critical for the development of 21st-century youth and align with the OECD's multidimensional sustainability framework.

What makes the model unique is its applicability not only within the Turkish context but also on a global scale. In low-income regions, community gardens supported by local governments and NGOs can take the lead; in more technologically advanced areas, digital storytelling and online sales platforms can be emphasized. This flexible structure allows the model to be adapted to different education systems, climate conditions, and cultural norms.

However, potential limitations in implementation should also be considered. These may include institutional resistance, insufficient preparedness of teachers for sustainability-based pedagogical approaches, or lack of collaboration at the local level. Nonetheless, strategic partnerships with municipalities or pilot projects through Erasmus+ school collaborations could enable initial implementation. The model can then be tested and scaled in diverse contexts.

In conclusion, this model positions young people not merely as passive recipients of environmental education, but as producers, organizers, and designers of a resilient future. In this respect, it offers a comprehensive organizational framework with the potential to transform education systems toward a sustainability-focused paradigm.

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Urban Sustainability Through Education: The Strategic Role of Educators in the Perspective of Child-Friendly Cities

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ABSTRACT

This study investigates the contributions of educators in Turkey to child-friendly city strategies and examines how these efforts impact urban sustainability. The aim is to evaluate the integration of children's rights and urban awareness themes into the national curriculum, analyze teachers' pedagogical approaches, and reveal the structural status of collaboration between local governments and educational institutions. The research was conducted using qualitative methods, including policy document analysis, case studies, and semi-structured interviews. Findings indicate that although teachers individually strive to prepare children for active citizenship, curriculum limitations and administrative constraints hinder these efforts. Cooperation with local governments was found to be limited and lacking in sustainability, while platforms such as children's councils were largely symbolic in function. The study concludes that in order to sustain the vision of child-friendly cities, educators must be systematically supported, curricula need to be restructured, and school-municipality partnerships must be strengthened. It is recommended that modules on urban participation and children's rights be integrated into teacher training programs.

Key words: Urban Sustainability; Child-Friendly Cities; Participatory Citizenship; Educational Policy; Children's Rights

Introduction

Urbanization is one of the most transformative forces shaping contemporary societies, dramatically altering physical environments, social structures, and governance systems. The United Nations predicts that by 2050, approximately 68% of the world's population will live in urban areas, compared to just 30% in 1950 (1). This urban growth brings opportunities but also deepens existing challenges, especially for children, who are both current urban residents and future citizens.

Children are uniquely affected by urban life. They experience cities differently from adults, encountering opportunities for education, culture, recreation, and participation, but also facing specific vulnerabilities: unsafe neighborhoods, pollution, lack of green spaces, and socio-economic inequalities (2). Recognizing these challenges, international frameworks have evolved to center children's rights within urban policy discourses. The Child-Friendly Cities Initiative (CFCI), launched by UNICEF in 1996, advocates for municipalities to systematically incorporate children's rights into urban governance (2). Its vision extends beyond the provision of parks and safe sidewalks: it calls for children to have a voice in shaping the urban environments they inhabit.

However, there is growing criticism that CFCI implementations worldwide have disproportionately emphasized physical infrastructure at the expense of deeper, systemic changes such as educational reform (Karsten, 2015; 10). In this respect, pedagogy—the means by which children learn about, understand, and engage with their urban environments—remains significantly underdeveloped.

In the Turkish context, this imbalance is pronounced. While Turkey has made legislative commitments to child welfare, including ratifying the UN Convention on the Rights of the Child (UNCRC) in 1995, practical implementation has focused largely on physical improvements (playgrounds, pedestrian zones) without sufficient attention to civic education. The Basic Law of National Education (Law No. 1739) highlights "social responsibility" as a key objective (5), but an analysis of the Türkiye Century National Curriculum (2024) reveals scant coverage of children's rights, civic agency, or urban governance (7). The curriculum focuses heavily on national identity, environmental issues framed in general terms (like recycling), and moral education, leaving significant gaps in preparing children for participatory urban citizenship.

By contrast, Scandinavian countries offer exemplary models where civic literacy is embedded from an early age. In Finland, "local democracy" is introduced in the lower primary curriculum and is integrated across subjects, encouraging children to engage with municipal decision-making processes (OECD, 2020). In Norway, children are introduced to the structure of local governments as part of their core curriculum and participate in school-based elections mirroring real-world democratic processes.

Theoretical frameworks reinforce the need for such pedagogical integration. Dewey (3) famously argued that schools should function as microcosms of democratic society, allowing students to practice participatory skills within their communities. Freire (4) expanded on this, conceptualizing education as a practice of freedom, essential for developing critical consciousness about one's environment and the structures shaping it.

Participatory learning environments, where students are actively involved in examining and influencing their immediate surroundings, have proven educational and social benefits (Braun & Clarke, 2006; 11). For example, in a comparative study of civic education practices, countries emphasizing experiential learning report higher levels of civic engagement among youth (OECD, 2020).

In Turkey, however, these pedagogical opportunities remain largely informal and teacher-dependent. While some educators independently initiate neighborhood projects or classroom discussions on urban life, such efforts are isolated and lack systemic support (6). They often occur outside regular lesson hours and depend on individual teacher motivation, without formal guidance, recognition, or institutionalization.

This study addresses this critical gap by systematically analyzing the role of Turkish educators in supporting the CFC vision. It examines how teachers navigate a curriculum that offers limited guidance on civic education, how they innovate pedagogically to foster urban awareness, and how they interact with municipal structures to promote children's participation. By situating these findings within a comparative international context, the study contributes to both educational policy and urban governance literature, advocating for integrated reforms that bridge the pedagogical and governance dimensions of child-friendly cities.

This research adopts a qualitative methodology grounded in interpretive paradigms, aiming to capture the complex, context-dependent nature of educators' contributions to child-friendly city initiatives in Turkey. A case study design was chosen for its ability to provide an in-depth understanding of the phenomenon in its real-life context (Yin, 2018).

The study employed three primary data collection strategies. First, a comprehensive document analysis was conducted, focusing on national and international policy documents, legislative texts, and reports. These included UNICEF's CFCI materials (2), Turkey's Basic Law of National Education (5), the 2024 Türkiye Century National Curriculum (7), and the Child Participation in Local Governments Report by the Union of Municipalities of Türkiye (9). This allowed for mapping both the formal policy framework and curricular provisions relevant to children's urban participation.

Second, two municipality-supported pilot projects in İzmir and Eskişehir were examined as case studies. These municipalities were selected because of their formal engagement with children's councils and past participation in CFCI-aligned initiatives. Data from these cases included project documentation, municipal reports, and public statements.

Third, semi-structured interviews were conducted with twelve primary school teachers and three municipal officials responsible for child participation programs. The teachers were selected from diverse socio-economic regions to ensure variation in institutional contexts and experiences. Interview protocols were designed to explore teachers' perceptions, practices, and challenges related to fostering children's civic engagement in urban environments.

All qualitative data were analyzed using thematic analysis (Braun & Clarke, 2006; 11), following a six-step process of familiarization, coding, theme development, review, definition, and reporting. NVivo 12 software facilitated the management and organization of codes and themes.

Methodology

This research employs a qualitative case study methodology, which is particularly suited to examining complex, context-dependent phenomena (Yin, 2018). The objective is not merely to document practices but to interpret the lived experiences, institutional structures, and policy frameworks that shape educators' contributions to child-friendly cities in Turkey.

2.1 Research Design and Rationale

A qualitative approach allows for a rich, in-depth exploration of the subjective experiences and institutional contexts influencing teachers' practices. The case study design facilitates detailed analysis of the interplay between curriculum, pedagogy, and municipal collaboration.

2.2 Data Sources

The research draws on three primary sources of data: Policy and Curriculum Documents: Analysis included the Basic Law of National Education (5), the Türkiye Century National Curriculum (2024) (7), and UNICEF's Child-Friendly Cities Handbook (2), enabling a critical examination of the policy frameworks governing child participation and education in Turkey.

Case Studies of Municipal Initiatives: İzmir and Eskişehir were selected as focal sites due to their reputations as leaders in implementing child-friendly policies and establishing children's councils.

Semi-Structured Interviews: Twelve teachers from diverse socio-economic regions and three municipal officials responsible for child participation programs were interviewed. Schools were purposively sampled to reflect variation in socio-economic status, geographic location, and prior engagement with municipal initiatives.

2.3 Data Collection:

Interview protocols were designed to probe participants' perspectives on: Curriculum adequacy regarding civic education; Institutional supports and barriers for fostering children's participation; Collaboration experiences between schools and municipalities.

2.4 Analytical Strategy

Data were analyzed using thematic analysis (Braun & Clarke, 2006; 11), adhering to a six-phase process: familiarization, coding, theme development, review, definition, and narrative construction. NVivo software was used to manage data systematically and ensure analytical rigor.

Document analysis provided a baseline understanding of formal policy commitments, while case studies and interviews revealed gaps between policy and practice. Triangulation of these data sources enhanced the credibility and trustworthiness of the findings.

2.5 Comparative Lens

A comparative dimension was embedded in the methodology. Insights from Finland, Norway, and Denmark served as benchmarks, enabling the identification of structural deficits and potential reform pathways for Turkey. This comparative analysis allowed the study to move beyond descriptive accounts toward normative recommendations grounded in international best practices.

Main Results and Discussion

This section presents and critically analyzes the key findings from the document analysis, case studies, and semi-structured interviews, situating them within a comparative international context. The discussion integrates empirical results with relevant literature to provide a nuanced understanding of the opportunities and challenges faced by educators in Turkey in advancing child-friendly city (CFC) objectives.

3.1 Curriculum Deficiencies and Comparative Insights

An in-depth review of the Türkiye Century National Curriculum (2024) reveals that it lacks systematic coverage of children's rights, participatory democracy, and urban governance. While "social responsibility" is framed as a core educational aim in the Basic Law of National Education (Law No. 1739) (5), in practice, this principle is interpreted narrowly—primarily as environmental responsibility or community service rather than active civic engagement.

For instance, the fourth-grade social studies syllabus contains references to environmental protection (e.g., recycling and litter reduction), but no content explicitly addresses how municipalities function, children's rights to participation, or mechanisms for influencing local decision-making (7).

By contrast, international best practices offer a starkly different picture. In Finland, civic education is introduced as early as Grade 1, where students engage in classroom elections and simulations of municipal council meetings (OECD, 2020). In Norway, local governance education is integrated into the national curriculum, and children are encouraged to participate in decision-making processes concerning their schools and neighborhoods (Karsten, 2015; 10). These examples demonstrate that civic literacy and participatory competencies can and should be cultivated from an early age, embedded structurally within national curricula.

Without such curricular scaffolding, Turkish teachers face the challenge of filling this gap independently—a task that is neither formally recognized nor structurally supported.

3.2 Teacher-Led Innovations and Pedagogical Strategies

Despite these deficiencies, many teachers demonstrate significant pedagogical creativity in promoting urban awareness and participatory citizenship. Interviews reveal a range of innovative practices:

Participatory urban audits, where students assess their immediate environments (e.g., sidewalks, crosswalks, playgrounds) for safety and accessibility.

Mapping exercises, where students identify resources and hazards in their neighborhoods.

Classroom discussions and debates on urban issues such as air pollution, traffic congestion, and equitable access to public spaces.

For example, in one case study from İzmir, a teacher facilitated a project where students conducted a neighborhood walk, documenting problematic areas for pedestrians and submitting a formal report to the local municipality. This practice mirrors Dewey's (3) call for experiential education—learning through active engagement with real-world contexts—and Freire's (4) conception of education as a means of empowering learners to transform their realities.

However, these efforts are highly individualized and reliant on teacher motivation. Teachers report that such initiatives are conducted during after-school hours or as informal projects, unsupported by curricular frameworks or formal teacher evaluation systems.

3.3 Institutional Fragmentation and Weak School-Municipality Collaboration

Data from the Union of Municipalities of Türkiye (2020) (9) indicate that only 23 municipalities have active children's councils, and less than half of these councils regularly involve schools in their operations. Even in municipalities that have formally established children's councils, teachers report being excluded from key processes such as candidate selection, election oversight, and agenda-setting.

This exclusion undermines both the councils' legitimacy and their effectiveness as mechanisms for meaningful child participation. As a result, councils often become symbolic rather than substantive forums—visible signs of commitment to CFC principles without fostering genuine engagement.

By contrast, Scandinavian models institutionalize formal partnerships between schools and municipalities, ensuring that civic education is integrated with real-world participatory opportunities (Karsten, 2015; OECD, 2020). For instance, in Finland, children's municipal councils are closely tied to schools, with teachers playing a formal role in facilitating children's participation and ensuring alignment with curricular goals.

3.4 Structural and Bureaucratic Barriers to Civic Education

Structural constraints emerged as a dominant theme in interviews. Teachers consistently cited several barriers impeding their ability to promote civic education and foster children's participation in urban life:

Rigid curriculum structure and time constraints: 75% of teachers reported that civic education activities must be conducted outside formal teaching hours due to heavy curriculum loads and the absence of dedicated time for such activities.

Bureaucratic procedures: Teachers described complex processes for obtaining parental consent and securing municipal and school administration approvals for projects, leading to delays and discouraging future initiatives.

Lack of formal recognition and support: Teachers expressed frustration that civic education efforts are not acknowledged in teacher performance evaluations or professional advancement criteria.

These barriers significantly limit the scalability and sustainability of teacher-led civic education initiatives.

Table 1. Key differences in civic education frameworks: Turkey vs. Finland and Norway

Dimension	Turkey	Finland	Norway
Civic education integration	Minimal; limited to environmental protection	Core component from Grade 1	Core component from Grade 1
Participation mechanisms	Fragmented; few municipalities with weak ties to schools	Strong municipal-school partnerships	Strong municipal-school partnerships
Institutional support for teachers	Limited; dependent on individual motivation	Formal recognition and institutionalization	Formal recognition and institutionalization
Barriers	Bureaucratic, rigid curriculum, lack of resources	Minimal; integrated structures	Minimal; integrated structures

Synthesis of Findings

Overall, this section reveals a disjunction between policy commitments to children's rights and the practical realities of education and municipal governance in Turkey. While teachers exhibit remarkable dedication and innovation, their efforts are constrained by systemic limitations. In contrast, international best practices show that embedding civic education into formal curricula, institutionalizing school-municipality partnerships, and reducing bureaucratic barriers are essential for fostering meaningful child participation in urban life.

The findings reinforce the argument that physical infrastructure improvements alone cannot achieve the aims of child-friendly cities. Pedagogical structures that cultivate children's civic awareness, political literacy, and participatory competencies must become integral to both educational and municipal policy frameworks.

Conclusion

This study contributes to a critical yet underexplored area at the intersection of education, urban governance, and children's rights: the strategic role of educators in realizing the vision of child-friendly cities (CFC) in Turkey. The findings demonstrate that although Turkish educators demonstrate creativity and commitment in nurturing urban awareness and participatory skills among children, they do so in an environment where formal curricular frameworks and institutional supports remain weak or absent.

Why does this matter? Because sustainable urban development is not simply about designing safe playgrounds or improving urban infrastructure. It is about cultivating a generation of citizens who possess the knowledge, skills, and dispositions to actively shape the urban environments in which they live. Without embedding civic literacy, political agency, and participatory competence into the formal education system, even the most progressive urban planning policies will fall short of achieving genuine inclusivity and sustainability.

This study's results highlight a structural tension: teachers are individually bridging a gap between policy rhetoric and educational practice, but these efforts remain fragmented, unrecognized, and unsustainable. Comparative evidence from Finland and Norway underscores the importance of structural embedding: where civic

Climate-Resilient Cities Through Children's Eyes: An Early Intervention Model with Ecological School Gardens

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ABSTRACT

This study is based on the idea that children are not merely passive individuals in urban life but can be active partners in sustainable urban transformation. Conducted in a preschool in Türkiye in collaboration with a university, this practice-based research involved the co-creation of an "ecological school garden" model with five-year-old children. The nature-based, participatory learning process offers micro-scale solutions to urban ecology, climate adaptation, biodiversity, renewable energy, and circular economy.

During the implementation, children contributed to the development of rainwater harvesting systems, raised garden beds irrigated through drip systems, urban farming plots, compost units, and bird observation areas. Harvested rainwater was used through drip irrigation in garden beds where vegetables and plants were grown. The study followed a qualitative design; children's environmental awareness, critical thinking, and social participation were assessed through observation and analysis of their products. Data were analyzed thematically using descriptive methods.

Findings show that children became not only learners but also environmentally aware individuals influencing their communities. The model presents a holistic contribution to the "children and cities" theme, integrating urban sustainability and ecology. It highlights the transformative role of early childhood education in fostering resilient, eco-conscious urban citizens.

Key words: Children and cities , Sustainable cities , Early childhood , Nature-based learning , Urban ecology

Introduction

Today's cities face significant environmental crises such as climate change, biodiversity loss, increasing resource consumption, and environmental pollution. These challenges necessitate the inclusion of children as active participants in sustainable urban planning. As future decision-makers and long-term inhabitants of cities, children are among the most important stakeholders in shaping urban futures. Gaining environmental aware-

ness at an early age is critical for achieving long-term sustainability goals. Increasing children's participation not only empowers them as active actors within urban ecological systems but also promotes environmental awareness across all segments of society. This study aims to examine the contributions of preschool children to urban ecology through the development of an ecological school garden model. Implemented in collaboration with a university, this hands-on initiative allows children to interact with and experience key sustainability concepts such as urban sustainability, climate change adaptation, and biodiversity in a meaningful and age-appropriate manner.
Existing literature highlights the positive effects of children's interactions with nature on their cognitive, emotional, and social development. These interactions help children develop a sense of responsibility towards the environment and adopt sustainable lifestyles (Sobel, 2004). However, studies exploring children's active roles in urban ecosystems and their potential in sustainable urban transformation are limited. This study aims to reveal what roles children can assume as active participants, beyond being passive observers, in the improvement of their urban environment. It is believed that environmental awareness gained in early childhood forms the basis for individuals to exhibit sustainable behaviors throughout their lives (Chawla, 1999). In this context, applied learning environments such as ecological school gardens allow children to understand abstract concepts through concrete experiences.

The core premise of this project is to increase children's awareness of environmental issues and encourage their active participation in solution processes. Today, cities have become centers where environmental pressures increase with rapid population growth and uncontrolled urbanization. This situation makes it essential to develop environmental sensitivity and a sense of responsibility, especially among younger generations. Additionally, the United Nations' Sustainable Development Goals (SDGs) emphasize the need for cities to become more sustainable, inclusive, and resilient (United Nations, 2015). The role of children in achieving these goals cannot be overlooked. The study demonstrates children's capacity to understand environmental concepts and integrate them into their daily lives from an early age. Thus, it offers an original and applicable approach to frequently discussed themes in the literature such as "children and cities," "urban sustainability," and "urban ecology."

This introduction provides a comprehensive overview for the reader by summarizing the study's purpose, scope, and methodology. By focusing on children's active role in urban ecology, it emphasizes the importance of shifting from a traditional passive student model to a paradigm where children can be active agents of environmental change. This approach encourages the reimagining of cities not only for adults but as inclusive environments shared by all age groups, enabling the development of more inclusive, resilient, and sustainable urban visions.

Method

This study was conducted using qualitative research methods. Qualitative research offers the opportunity to examine phenomena in depth and to understand participants' experiences and perspectives (Creswell, 2014). Particularly in the fields of education and environmental sciences, qualitative approaches are preferred to understand complex social processes and behaviors. In this context, this method was adopted to holistically examine the effects of the ecological school garden model on children's environmental awareness and behaviors.

Study Group and Ethical Approach

The study group consisted of twentyfive-year-old children attending Kaptan Altay Altuğ Kızılay Kindergarten in Düzce, Turkey. Participant selection was based on voluntary participation, and informed consent was obtained from school administrators, teachers, and children's parents before the research process. This ethical process ensured the transparency of the research and the protection of participants' rights. Due to children being a sensitive group, ethical principles were strictly observed during data collection and analysis processes. Each child's participation was on a voluntary basis, and children who did not wish to participate in activities were respected.

Data Collection Tools

Data were collected through observations of children in their natural learning environments and through tangible outputs they produced during activities (e.g., drawings, creative works, handmade products).

Observations: Researchers systematically observed children's behaviors, interactions, and reactions to environmental concepts during activities in the ecological school garden. Observations were recorded using structured observation forms and researcher journals. These observations provided in-depth information about children's critical thinking skills and social participation regarding environmental issues.

Children's Products: Tangible products created by children during activities, such as drawings, models they built (e.g., rainwater harvesting systems), plant plantings in garden beds, and their roles in composting, were used as data sources. These products offered rich evidence of how children understood and internalized environmental concepts. For example, children's drawings on themes of water conservation or recycling reflected their mental processes and levels of awareness.

These multiple data sources increased the reliability of the findings (Creswell, 2014). Bringing together different types of data allowed researchers to check for consistency across data and reach more comprehensive conclusions.

Data Analysis

Descriptive analysis method was used to examine the data. Data obtained from observations and children's outputs were grouped under specific themes and interpreted. The analysis process included the following steps:

Data Coding: Collected observation notes and children's products were coded under relevant themes such as environmental awareness, problem-solving, collaboration, and respect for nature.

Theme Generation: Common patterns and relationships among the coded data were examined to form main themes and sub-themes. For example, concepts like "water conservation" or "waste separation" were combined under a broader theme of "environmental responsibility."

Thematic Interpretation: The generated themes were interpreted in depth in light of the literature and in line with the study's objectives. In this stage, changes in children's environmental behaviors and their acquired new knowledge were explained.

Researcher consensus ensured analytical rigor, and ethical rules were strictly adhered to throughout the study. Independent coding of data by multiple researchers and subsequent comparison of these codings increased the objectivity and reliability of the analysis.

Implementation

The implementation process was structured around five main nature-based themes that encouraged active children's participation and direct interaction with nature. These themes allowed children to understand concepts such as sustainability, ecological cycles, and renewable energy from an early age through play, observation, and collaboration (Sobel, 2004).

Rainwater Harvesting Systems

Children designed and built rainwater harvesting systems in the school garden using recycled materials (plastic bottles, old buckets, faucet connections). Through this hands-on activity, they gained experiential knowledge about the natural water cycle, the importance of rainwater conservation, and its role in drought mitigation. This exercise not only raised awareness about sustainable water use but also developed their recycling skills, engineering thinking, and collaborative abilities (Liu et al., 2003). Children personally witnessed how collected rainwater could be used to water plants in the garden and in this process gained a better understanding of the value of water.

Drip Irrigation Systems and Urban Gardening

In the vegetable beds created in the garden, children actively participated in all stages from seedling planting to harvesting. They observed plant growth cycles and applied irrigation and soil cultivation techniques. The use of harvested rainwater in drip irrigation systems provided practical knowledge about water efficiency and environmentally friendly agricultural practices. By observing the growth processes of vegetables they cultivated themselves, children developed a direct understanding of where food comes from and the cycles of nature. This experience also laid the foundations for healthy eating habits.

Compost Production

During composting activities, children separated organic waste (fruit/vegetable peels, leaves) and created compost piles. In doing so, they observed organic matter cycles and the roles of microorganisms firsthand, facilitating an early understanding of circular economy principles (Girardet, 1999). Children saw how materials perceived as “waste” were actually transformed into valuable resources that enriched the soil, and they grasped the environmental benefits of this transformation. This activity enabled them to acquire basic knowledge about waste management and resource efficiency.

Biodiversity Observation Areas

Through the theme of biodiversity, which included bird observation stations and nature walks, children had opportunities to understand local ecosystems and develop a sense of conservation awareness. These activities were observed to also increase environmental awareness among families and contribute to the adoption of sustainable practices in households (Louv, 2005). Children learned to identify different plant and animal species in their gardens, understanding the importance of ecological balance and the role of every living creature in the ecosystem. These observations reinforced their empathy and respect for nature.

Findings and Discussion

The findings of the study clearly demonstrate that preschool children developed significant awareness of environmental issues and acquired basic critical thinking skills. Especially through hands-on activities involving direct interaction with nature, it was observed that children perceived the environment not just as an object of observation, but as a living space in which they actively participated.

Environmental Awareness and Critical Thinking Skills

Teacher journals and child observation forms indicated that children asked questions in their own words about environmental pollution, water waste, energy saving, recycling, and the protection of living beings. They offered simple but thoughtful solutions to these concerns and showed emotional reactions to these issues (Hart, 1997). For example, some children were reported to have started using water more carefully at home and reminding their families to separate plastic packaging for recycling instead of throwing it in the trash. These behaviors demonstrate that children not only acquired knowledge but also internalized it and reflected it in their daily lives (Chawla, 2002; Hart, 1997).

Observational data and the creative products children produced during activities revealed a concrete improvement in their understanding of environmental concepts. Behaviors such as waste sorting, water conservation, and showing empathy towards nature during play proved that children not only gained knowledge but also internalized it and reflected it in their behaviors. Children's drawings, structures they built, and material-based products showed that they expressed environmental themes in unique and creative ways. These findings indicate that young children can develop an environmentally sensitive perspective and grasp basic ecological concepts from an early age (Sobel, 2004). Therefore, children's environmental learning experiences contributed holistically to their cognitive, emotional, and behavioral development (Tilbury, 1994).

Children's Active Stakeholder Role and Urban Sustainability

The data indicate that even in early childhood, children can grasp abstract concepts such as sustainability, urban resilience, and ecological responsibility through concrete, application-based learning environments. In this context, the ecological school garden model offered children an experience beyond that of passive learners; it positioned them as active agents in urban life and environmental participation. Throughout the implementation process, it was observed that children not only gained knowledge but also planned, questioned, and transformed their own environmental actions (Newman & Jennings, 2008).

As such, the model offers an original and applicable approach to frequently discussed themes in the literature such as "children and cities," "urban sustainability," and "urban ecology." It supports the idea that urban areas should be designed with children's developmental needs in mind, that children's perspectives should be integrated into urban planning processes, and that child-centered participation is critical not only in education but also in shaping environmental and spatial policies (Agyeman, Bullard & Evans, 2003). This approach invites us to reimagine cities not only for adults but as inclusive environments shared by all age groups, thus enabling the development of more inclusive, resilient, and sustainable urban visions.

The findings indicate that children did not limit their environmental responsibilities to the school environment but also carried these behaviors into their family and community lives. This situation reveals how powerful a catalyst early childhood education is in creating environmental awareness. By transferring what they learned to their parents and other adults around them, children indirectly contributed to increasing environmental awareness in a wider audience. This ripple effect holds significant potential for achieving sustainable urban living goals.

Conclusion and Recommendations

This study has demonstrated that preschool children can meaningfully engage with concepts such as environmental awareness and urban sustainability through experiential learning and active participation. The developed ecological school garden model revealed that children are not merely passive learners but active individuals who can play a role in shaping their living environments. Through nature-based activities, children's critical thinking, observation, collaboration, and responsibility skills were strengthened, while families and the broader school community also exhibited positive changes in their attitudes towards the environment. The findings highlight the importance of integrating child-centered approaches into urban ecological policies.

In this context, the following recommendations are presented :

Transform school gardens into living learning environments: Micro-scale ecological areas should be planned and designed. In these areas, children can directly interact with nature, observe environmental systems, and experience sustainable living practices. These gardens should be seen not only as play areas but as experimental spaces where science, art, and environmental education intersect. Areas where children can grow their own food, make compost, and experience the water cycle will solidify theoretical knowledge, supporting lasting learning (Liu et al., 2003). Such hands-on learning environments will also contribute to children's development of 21st-century skills such as problem-solving, creativity, and teamwork.

Support child participation in urban design processes: Local governments and planning authorities should develop participatory models that include children's perspectives and needs. Children should be actively involved in the design of public spaces such as parks, gardens, and playgrounds. This participation will strengthen their sense of belonging to the urban environment and ensure that these areas are more livable and functional (Hart, 1997). Hearing children's voices and evaluating their ideas forms the basis of democratic participation and prepares the ground for future generations to grow up as more responsible individuals towards the environment.

Encourage university-school partnerships: Collaborative projects with academic institutions offer children exposure to scientific processes at an early age while grounding sustainability practices on research-based foundations. These partnerships also promote interdisciplinary and community-based approaches in education. University-school collaborations facilitate the dissemination of scientific knowledge to the community and contribute to the development of innovative methodologies in education. Additionally, they support the professional development of teachers, improving the quality of sustainability education.

Expand ecological awareness through family and community participation: The learning process initiated at school should continue at home and be reinforced through community-level activities that increase environmental awareness. Initiatives such as family workshops, community gardens, and neighborhood ecology days can support this goal. Such community-based approaches encourage the adoption of sustainable lifestyles not only at the individual level but also at the societal level. The adoption of environmentally conscious behaviors by families and communities serves as a strong role model for children to reinforce what they have learned (Louv, 2005).

In conclusion, this study has clearly demonstrated that children can serve as conscious and active stakeholders in shaping the cities of the future. Environmental learning models introduced in early childhood education provide a strong foundation for building more resilient and sustainable urban environments. Expanding and supporting this model is a critical step towards sustainable urban transformation that encompasses not only today's children but also future generations. The bonds children form with nature at an early age will enable them to develop lifelong environmental awareness (Chawla, 1999). This, in turn, will pave the way for broader societal change and the adoption of sustainability-oriented policies.

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The Right to Mobility is a Human Right: Transport for All, Lifelong Mobility

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ABSTRACT

Although the physical structures and transportation infrastructure of urban areas are accessible to most individuals, disadvantaged groups such as people with disabilities, the elderly, children, pregnant women, and women face serious access problems in these areas. This study aims to examine the physical barriers that disadvantaged individuals encounter in transportation, mobility, and access to structures in the context of sustainable urban mobility through a literature review. Sustainable urban mobility aims not only to reduce environmental impacts but also to promote an inclusive urban life that respects the independent, safe, and equal access rights of all individuals. The literature review categorises the issues under four main headings: transportation vehicles; sidewalks and pedestrian paths; educational, health, and work structures; and entertainment, recreation, and sports areas. The principles of the European Urban Charter regarding transportation and mobility emphasise that transportation should not be viewed merely as a technical service but as a fundamental condition for individuals' participation in social life. In line with this principle, solutions have been proposed for each category to strengthen disadvantaged individuals' access to urban areas and ensure their equal participation in social life. This study emphasises that accessibility is a fundamental right not only for disadvantaged individuals but for all individuals who may encounter situations such as ageing, illness or temporary mobility restrictions at any stage of life. With this understanding, a model of an inclusive city that improves quality of life is proposed. Therefore, efforts to enhance the accessibility of the physical environment should be addressed through a comprehensive approach that supports social participation, prioritises spatial accessibility, and aligns with sustainable development goals.

Key words: Sustainable Urban Mobility, Accessibility, Disadvantaged Groups, Universal Design

Introduction

Sustainable transport is defined as a system that enables the basic access needs and development of individuals and communities to be met in a safe manner that is compatible with human and ecosystem health. Sustainable development, as defined in the Brundtland Report, is 'meeting the mobility needs of both the present and the future by protecting and improving human and ecosystem health, economic development, and social justice' [1].
Sustainable transport encompasses urban mobility and urban transport. The difference between sustainable urban mobility and sustainable urban transport is that the former refers to 'action' while the latter refers to static physical infrastructure. Urban mobility refers to taking action in line with goals and needs, creating

dynamism by changing locations, while urban transport refers to the overall state of the infrastructural system created to utilize mobility opportunities in a broader context.
Urban mobility refers to movement or transportation that takes place in urban areas. Urban mobility occurs when our journey from the moment we leave home to the moment we return home passes through at least one urban settlement [2]. Sustainable urban mobility means not only ‘protecting basic human or ecological values but also ‘meeting people’s need to move freely, access places, and connect with others [3].
Disadvantaged individuals are unable to leave their homes, which are seen as compulsory living spaces, due to the lack of urban space regulations and facilities tailored to their needs, and they are unable to benefit from basic rights granted to them by law, such as education, health, work, leisure, rest, and sports. The aim of this study is to highlight the difficulties disadvantaged individuals face in transportation, circulation, and access to buildings in urban areas and to make recommendations regarding the necessary urban and architectural arrangements.
Disadvantaged groups face problems with transportation and mobility in urban areas. The main problem is that people with disabilities cannot access urban spaces and buildings that other user groups can access easily and without difficulty. The vast majority of disadvantaged groups express dissatisfaction with the physical environment in their living areas [4]. Although various institutions and organizations have been established to coordinate regulations in this area, disadvantaged groups have not yet been able to actively benefit from urban areas and structures to the desired extent.
European Urban Rights evaluate the right of individuals to live in a safe, healthy, and quality urban environment, along with equal access to basic services and areas such as work, movement, health, sports, and recreation, and define these elements as indispensable components of urban life [5].
The European Urban Charter Principles define how cities should be in order to ensure that every individual has the rights defined in the European Urban Rights, while also emphasizing architectural arrangements for the use of urban areas and structures by disadvantaged groups such as disabled, elderly, and child users, who are often overlooked in our cities. Within the scope of the European Urban Charter principles, the creation of barrier-free, liveable, usable, and accessible urban spaces and structures, raising awareness of disadvantaged groups, and improving the quality of urban life are targeted [6,7].
Prioritizing sustainable mobility solutions, the European Urban Charter encourages the balanced and integrated development of all modes of transport to ensure they are accessible to all segments of society. The Charter includes a total of 13 principles, with the fundamental principles related to transport and mobility grouped under four headings: (1) developing strategies to reduce private vehicle use; (2) structuring transportation systems in a multifaceted and alternative manner that enables the creation of liveable cities; (3) evaluating public streets as areas for social interaction; and (4) the necessity of continuous education and awareness-raising activities to increase social awareness.
In this study, the transportation and mobility problems of disadvantaged groups in urban areas were examined under five headings: transportation vehicles, sidewalks and pedestrian paths, education, health and work structures, and recreation, leisure, and sports areas. Solution proposals were presented for each category.

1. Problems Related to Transportation of Vehicles

• Failure to implement established standards for public transportation and private vehicles accessible to persons with disabilities
• Lack of public transportation vehicles designed or adapted for persons with disabilities
• Irregular and inconsistent transportation services
  o Uncertainty regarding bus schedules and stop locations
  o Insufficiently simple and understandable informational materials for people with intellectual disabilities
• Insufficient parking spaces reserved for people with disabilities and existing parking spaces being occupied by private vehicle owners

2. Issues Related to Sidewalks and Pedestrian Routes

- Sidewalks and pedestrian routes that are non-standard and variable in terms of width and height
- Sidewalks and pedestrian routes that are uneven, rough, or slippery
- Absence of ramps or failure to meet the 6% slope standard
- Uneven, rough, or slippery floor coverings
- Occupation of sidewalks and pedestrian paths by vehicles
- Irregular placement of urban furniture and other elements that obstruct access
    - o Bus stops, lighting poles, mushroom-type barriers, displayed products, irregular urban furniture, etc.

3. Problems Encountered in Education, Health, and Work Buildings

- Architectural details:
    - o Walls with sharp corners and surfaces that could cause injury
    - o Inadequate acoustic arrangements
- Physical accessibility:
    - o Inaccessible building entrances and interior passageways
    - o Inadequate vertical circulation systems (elevators, ramps, etc.)
    - o Disabled toilets that do not meet accessibility criteria
- Equipment and signage:
    - o Signs, signage systems, door handles, electrical switches, etc., are not in the appropriate location or at the appropriate height
- Common areas
    - o Cafeterias, libraries, and laboratories lack accessible design features in particular, there are no audio systems for the visually impaired

4. Problems Identified in Recreation, Rest, and Sports Areas

- Inadequate signage and information systems:
    - o Signs lacking visual and auditory support
    - o Information not being simple and accessible
- Physical infrastructure deficiencies:
    - o Insufficient number and quality of toilets, changing rooms, and private areas
    - o Lack of seating and inappropriate placement of seating in rest areas
    - o Lack of sheltered structures and inadequate climate control
- In sports areas:
    - o Lack of accessible exercise and sports equipment

Recommendations for Transportation Vehicles:

Regular and continuous transportation services (consistent bus schedules and stops, written information for people with mental disabilities communicated in simple language) are practices that will facilitate access to transportation vehicles for disadvantaged individuals. In order to create safe areas for disadvantaged individuals, vehicle density and speed should be reduced in city centers, and non-motorized alternative transportation and public transportation should be used. Some disadvantaged individuals use specially designed vehicles. Therefore, a sufficient number of disabled parking spaces should be allocated in proportion to the existing parking areas. Transportation vehicles should have free Wi-Fi and provide the necessary visual and audio information, and the materials used for this purpose should be inspected frequently. Drivers should be required to receive training in disability awareness. Seats reserved for disabled individuals on buses should be standardized. Bus stops should be designed to be easily accessible to pedestrians, with locations that are easy to understand and visible from a certain distance. Bus stops should be covered, have seating, and have areas where wheelchair users can move independently; sidewalks should be made accessible with ramps of appropriate slope. Bus stops with transparent surfaces such as glass that are difficult to perceive should be marked with 7.5 cm wide contrasting colored warning strips on both the inner and outer surfaces at a height of 130 cm-140 cm for the first level, 90 cm-100 cm for the second level, and 10 cm-30 cm for the third level. The height of the bus stop signs from the ground should be at least 220 cm. Sufficient lighting should be provided at the bus stops.

Accessibility Regulations at Train Stations and Airports

Due to inadequate infrastructure in areas such as train stations and airports that operate 24/7, many individuals with disabilities require staff assistance in order to travel. This situation limits individuals' right to independent movement and equal access to services. Therefore, standardization of indoor accessibility must be ensured, and effective passenger assistance programmers must be implemented.

Passenger assistance services should be provided at specific times at each stop and station, with reservations made in advance; these reservations should be made by the passengers up to two hours before the journey. Assistance without a reservation should be provided when reasonably feasible.

The complexity of the decision-making process during ticket reservation and the inadequacy of alternatives, such as inaccessible ticket vending machines, create additional barriers for persons with disabilities. Therefore, ticket sales systems should be simplified, and accessible options should be increased.

For individuals who cannot stand for long periods of time, ticket queues at stations and airports should include bars to lean on; these bars should be wide enough to allow wheelchairs and prams to pass through. Informative leaflets should be distributed and placed in easily accessible locations.

Waiting areas and cafeterias should be made accessible, and special rooms with seating areas should be created for individuals with autism spectrum disorder, dementia or cerebral palsy. Rest areas should include sections suitable for guide dogs for individuals travelling with guide dogs.

Trains should provide sufficient space for wheelchair users, and these areas should be expanded to accommodate individuals with disabilities. During the ticket purchase process, systems should be developed that give priority to disabled individuals in the selection of open seats. These systems should be monitored; for example, individuals who use crutches, tripods, walkers, or guide dogs should be given priority in seat selection.

All toilets should be designed to be accessible in a way that allows independent movement; mainline train stations should allow step-free access or provide level boarding from the street to the platform (e.g., the train floor should be at the same level as the platform) [8].

Recommendations for Pavements and Footpaths:

To ensure that people with disabilities and disadvantaged individuals can move around comfortably and without difficulty on pavements and pedestrian walkways, there must be sufficient space for movement, free space below head height (free of plants and signs that pose a hazard), a flat and non-slippery surface with contrasting colors, the presence of guidance and warning devices, and simple, understandable, visually and audibly supportive materials. The pavement and pedestrian path surface must be slip-resistant and facilitate movement. The fixtures and fittings on the surface (manhole covers, grates, etc.), trees, billboards and advertising panels, flower beds, rubbish bins and similar urban furniture should not contain any arrangements that would endanger the mobility of persons with disabilities and interrupt the continuity of access. There should be no plants or signs at head height below 220 cm on the pedestrian path that pose a hazard.

The height of the kerb separating the pedestrian pavement and the vehicle road should be no less than 3 cm and no more than 15 cm, and a ramp with a width of 90 cm and a maximum slope of 8% should be installed at an appropriate location on the pavement at pedestrian crossings. There should be no trees, billboards, flower beds, rubbish bins or similar urban furniture on the pedestrian walkway and pavement. Simple markings, directional and informative equipment that can be perceived and interpreted by people with intellectual disabilities should be used on pedestrian walkways and pavements [9,10].

Recommendations for Areas Used for Recreation, Relaxation, and Sports:

Public areas such as parking lots should have wide spaces, pedestrian paths, entrances, and parking lots that allow children, adults, and the elderly to enter and exit with their vehicles. Protection against adverse weather conditions should be provided, and adequate lighting should be available. Rest stops should be placed along long paths in recreational, park, and open areas. Plants and surrounding structures should not be located at eye level in a way that could cause harm, and plants should be regularly inspected to ensure they do not pose a risk to people. Structures such as rest areas, concert halls, and open-air theatres should be designed according to the needs of disadvantaged individuals. The size of seats or seating areas, accessibility to these spaces, and objects that can be used in common areas within the space (taps, barbecue areas, exercise equipment, etc.) should be arranged so that they are accessible to everyone [11]. Accessible relief maps should be placed at the entrances to the areas to support the independent movement of users. Sports areas should be designed so that all individuals, whether disabled or not, can benefit equally; their architectural and hardware features should comply with universal design principles.
Each piece of sports equipment should have signs providing information, guidance, and warnings regarding its use; these signs should be simple and understandable, especially for individuals with cognitive impairments, and should be supported by visual and auditory materials.

Recommendations for Buildings Used for Education, Health, and Work:

Buildings accessible to individuals with disabilities should be designed to eliminate physical barriers both indoors and outdoors. Wall and door edges should be rounded, surfaces should be smooth, and passageways should be free of sharp protrusions. Floors should be non-slip, and thresholds and mats should be at the same level as the floor. From the entrance onwards, directional signs, colored markings, Braille alphabet, and audio systems should be used; visual symbols should be used for individuals who cannot read or write. The building should be single storey if possible; multi-storey buildings should have lifts, ramps, and wheelchair lifting systems. Doors, corridors, toilets, and equipment for wheelchair users should be at accessible heights; doors should be designed to show the opposite side. The location and structure of buildings and libraries used for education should be such that they are not affected by external noise. Tables and chairs should be movable, and the heights of some furniture should be adjustable. Furniture should have rounded edges rather than sharp ones. The space between desks should be wide enough to allow for easy passage. In areas with fixed seating, there should be sufficient space for wheelchair users. Sound amplification devices should be installed in areas where large groups will be trained and gathered. Countertops, taps, work desks, and sinks should be arranged so that everyone can use them independently. Taps should be designed to be opened and closed with a lever rather than by turning [4,5,12].
In order for disadvantaged individuals to actively participate in society and urban life and enjoy equal access to fundamental rights, accessibility must be taken into account not only in housing but also in all structures such as educational, healthcare, office, and park facilities. In this context, access, guidance, emergency safety, and building design principles should be comprehensively addressed by designing and implementing standards for access to the building first, and then to spaces within the building.

Conclusion

Disadvantaged individuals should not be viewed as a separate group from society, but rather as a natural and integral part of the social structure. Cities should be designed and organized in a way that ensures equal access to fundamental rights for all individuals. Accessibility is of vital importance not only for people with disabilities, but also for anyone who may encounter situations such as ageing or temporary or permanent mobility limitations. Therefore, all urban environment elements, from transportation systems to public buildings, should be designed in accordance with accessibility principles, and inclusive solutions should be implemented in areas such as guidance, circulation, safety, and comfort. This approach is a fundamental requirement for sustainable and equitable urban living.

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Climate-Adaptive Strategies in Vernacular Architecture of Mountainous Rural Settlements: Comparative Insights from Türkiye and China

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ABSTRACT

This research investigates climate-adaptive strategies embedded within the vernacular architecture of two mountainous rural settlements, Fındıklı in Rize, Türkiye, and Jinjiang Chalet Village in the Changbai Mountains, China, each characterized by distinct climatic and topographic conditions. These ecologically vulnerable regions face escalating environmental challenges such as intensified rainfall, landslides, floods, temperature fluctuations, and thermal stress due to global climate change. Drawing upon a comparative architectural analysis, the study explores how passive design strategies, such as site-specific orientation, natural ventilation, thermal insulation, spatial layout, roof structure, and integration with terrain, have evolved as practical responses to local climatic pressures. The research reveals both shared principles and regionally unique construction techniques grounded in centuries-old traditional ecological knowledge. Fındıklı demonstrates adaptive responses to high precipitation and soil instability, while Jinjiang reflects resilience to cold climate extremes and topographic constraints. Beyond identifying architectural features, the study highlights the socio-cultural and environmental rationality underlying vernacular forms, offering a valuable knowledge base for contemporary sustainable development and climate-resilient rural planning. The findings advocate for a hybrid approach that bridges indigenous architectural wisdom with modern ecological design and risk-sensitive spatial planning. Such integration is essential for enhancing the resilience, sustainability, and cultural continuity of mountainous rural communities in the face of accelerating environmental change.

Key words: Vernacular architecture, Mountainous rural settlements, Climate resilience, Climate adaptation, Traditional building practices

Introduction

Mountainous rural regions are particularly vulnerable to climate change due to their vulnerable ecosystems, steep terrain, and settlements often located in narrow valleys with limited land availability. These areas are increasingly exposed to intensified natural hazards, such as landslides, river floods, and droughts, which are projected to become more frequent and severe under global climate change scenarios (Pörtner et al., 2019; Kato et al., 2021). Moreover, the competition between land uses, such as agriculture, tourism, housing, and infrastructure, limits their adaptive capacity and increases environmental stress

(Huber et al., 2013). In response to these challenges, vernacular architecture has gained recognition as a climate-resilient model shaped by centuries of local experience. Built with indigenous materials and adapted to site-specific climate and topography, vernacular structures often demonstrate high levels of energy efficiency, passive environmental control, and spatial harmony with nature (Oliver, 2006; Zhang et al., 2018). Recent studies confirm that such traditional practices offer valuable insights into sustainable settlement planning under changing climate conditions (Philokyprou et al., 2017; Aktürk & Fluck, 2022).

This study investigates how vernacular architecture in two ecologically vulnerable mountain settlements, Fındıklı in Rize (Türkiye) and Jinjiang Chalet Village in the Changbai Mountains (China), reflects adaptive responses to climate and environmental risks. Through a qualitative comparison based on literature, the research analyzes building orientation, material use, and environmental integration. It aims to identify both shared and context-specific climate-adaptive strategies that inform resilient rural architecture in similar topographic and climatic settings globally.

Methodology

This study adopts a comparative qualitative research methodology to examine the climate-adaptive strategies embedded in vernacular architecture from two geographically and climatically distinct mountainous regions: Fındıklı in Rize, Türkiye, and Jinjiang Chalet Village in the Changbai Mountains, China. The methodological framework consists of the following key steps:

1. **Case Selection:** The two case study locations were purposefully selected due to their ecological vulnerability, pronounced climatic variability, and rich vernacular architectural heritage. Fındıklı represents a humid subtropical Black Sea context, while Jinjiang represents a severe cold region in Northeast Asia.
2. **Literature-Based Data Collection:** Architectural and environmental data for both settlements were gathered from scholarly literature, including journal articles, dissertations, field studies, and official climate records. Sources include primary works such as Aktürk (2023) for Fındıklı and Zhao et al. (2025) for Jinjiang.
3. **Comparative Analysis Framework:** The study uses a matrix-based approach to compare architectural features related to climate adaptation. These features include:
   - Site characteristics (elevation, slope, rainfall, temperature patterns)
   - Building orientation and spatial configuration
   - Material use and thermal performance
   - Passive ventilation and daylighting strategies
   - Roof and wall design elements
   - Integration with topography
4. **Synthesis and Interpretation:** The data were analyzed thematically to identify common principles and context-specific adaptations. Emphasis was placed on passive design logic, ecological integration, and disaster risk responsiveness.

Main Results and Discussion

The vernacular architecture examples from Türkiye and China are presented in Figure 1. According to the determined factors, the selected examples are compared in various criteria in Table 1. The comparative assessment of vernacular architecture in Fındıklı (Rize, Türkiye) and Jinjiang Chalet Village (Changbai Mountain Region, China) reveals several common principles and region-specific strategies for adapting to climatic conditions and disaster risks through the use of passive design elements and local construction techniques.


A vernacular architecture example from Fındıklı, Rize.
Source: Alkan, 2023


A vernacular architecture example from J
Source: Zhao et al, 2025

According to the analysis by Fındıklı in Rize, it is observed that topography is a key factor in settlement and construction decisions. The masonry stone system built up to the first floor protects the building against the adverse effects of soil moisture and rainfall. Additionally, the locally specific wall type "göz dolma," built using local materials such as stone and wood, is a distinguished element of vernacular architecture. Here, the designed wall, made with local materials, serves as an insulator due to the thermal mass effect of the stone. Moreover, the use of natural materials such as stone and wood together creates an environmentally sensitive and harmonious design approach. Furthermore, it acts as a protection against the excessive humidity in the region. The windows, which serve as elements of natural light and ventilation, are positioned according to the prevailing wind direction to minimize the adverse effects of cold and precipitation. The eaves, which extend up to 150 cm, serve as shading elements and protect the building from precipitation. Although there has been a decrease in snowfall in recent years, in previous years, the roof was built with four ridge slopes, mid-sloped against the snow load. Timber trusses, beams, and studs carry and hold the weight of the roof.

Table 1. Comparison of selected examples

		Fındıklı, Rize, Türkiye	Jinjiang Chalet Village, the Changbai Mountain Region, China
Site characteristics	Climate	Mild climate	Cold climate
	Height above sea level	~ 0-500 m	~ 500-2700 m
	Average slope of the site	~ 15-30%	~ 0–73%
	Average temperature in winter	~ 5ºC	~ -2ºC
	Average temperature in summer	~ 23ºC	~ 17ºC
	Temperature differences between day and night in winter	~ 5ºC	~ 10ºC

Site characteristics	Temperature differences between day and night in summer	~ 6ºC	~ 8ºC
	Average rainfall in winter	140-180 mm	~ 20 mm
	Average rainfall in summer	170-230 mm	~ 140 mm
	Average snowfall in winter	3-20 cm	2,5-8 cm
	Average snowfall in summer	None	None
	Prevalent wind direction	Northwest and west	Southwest and northwest
	Topography relations	Benefit from the topography for building placement. Buildings are far away from each other. The corn and tea fields are laid out in front of the dwellings, which are located on the highest point of the steep terrain, making the site useful.	The village was settled 30 m above the Songhua River's flood level.
Building characteristics (The data adopted from Aktürk, 2023; Zhao et. al, 2025).	Building orientation	The main entrance of the buildings is generally oriented in the north or northeast direction to minimize wind effects.	The residences are housed in different positions on the sunny slope linearly. The main entrance of the buildings is located to the south.
	Wall design – thermal insulation	Timber-framed stone infill (göz dolma). Stone creates a thermal mass effect for insulation. The ground floor is primarily used as a barn, while the first floor is reserved for living spaces. Animals live in a barn, which makes the air warm, and it helps to make the first floor warmer in winter.	The building's form and envelope are designed to minimize heat loss. "Mukeden" is constructed as a pure wood load-bearing structure, featuring wood shingles and wood chimneys to withstand challenging climatic conditions. Uniquely designed firewall with wood and mud, and a wood chimney heating system.

Building characteristics (The data adopted from Aktürk, 2023; Zhao et. al, 2025).	Natural daylighting and ventilation	The south and east sides have larger windows, while the north and northwest sides have fewer and smaller windows.	To utilize sunlight efficiently, buildings with surrounding trees are positioned high in the south and low in the north. The courtyard space allows more sunlight to enter the building. Buildings are erected to block the winter monsoon, forming a weak wind area that reduces the frost effect and freshens the air.
	Shading and solar control	Extended eaves to 150 cm.	Surrounded buildings with trees considering the sun path.
	Local material	Wood (chestnut, pine) and stone collecting from the river(s) as local materials.	Wood and mud.
	Roof design	Mid-sloped	Mid-sloped

The analysis of Jinjiang Chalet Village in the Changbai Mountain Region (China) shows that site characteristics form the vernacular architecture dominantly. The village maintains a well-balanced natural landscape with minimal impact on nature, thereby conserving the forest. The buildings are oriented to benefit from sunlight on the terrain. The buildings are constructed with wood as a whole structure, including the foundation, walls, chimney, and roof, which serve as a thermal insulation system. Additionally, a uniquely designed firewall, constructed with wood and mud, and a wood chimney, creates a well-designed heating system for the structure. The buildings are oriented to consider sun paths and wind directions, allowing for efficient use of sunlight and natural ventilation. Traditional material efficiency principles are applied to minimize waste and maximize environmentally friendly applications for construction.

From a disaster resilience perspective, both cases reflect adaptive capacities rooted in traditional knowledge: Fındıklı demonstrates responsiveness to hydro-climatic threats, such as floods and landslides, while Jinjiang showcases resistance to cold-related hazards, including frost, snow, and thermal stress. Both regions integrate passive design strategies, including material use, orientation, topographic integration, and environmental control, into vernacular construction to enhance energy efficiency and climate resilience.

Conclusion

The comparative research demonstrates that vernacular architecture contains centuries of adaptive knowledge, providing sustainable and site-specific solutions to local climate, topography, and environmental constraints. These traditional buildings are not only physical structures but comprehensive systems designed in harmony with nature. In both case studies, architectural decisions, such as orientation, material choice, and spatial layout, demonstrate a deep understanding of local dynamics and passive climate control. However, with the increasing frequency of disasters such as floods and landslides due to global climate change, the need to preserve the authenticity of vernacular architecture while adapting them to evolving risks becomes more urgent. Failure to integrate such considerations may leave these buildings highly vulnerable to extreme events. Likewise, in contemporary development practices, neglecting nature-based settlement principles — such as avoiding construction in floodplains or disregarding the use of local materials — can result in significant human and material losses. A resilient future lies in learning from these vernacular models: integrating traditional wisdom with modern risk-sensitive planning and design to ensure both cultural continuity and environmental harmony.

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Prediction of Ömerli Dam Water Level Using Artificial Neural Networks

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ABSTRACT

Forecasting dam water level is significant for sustainable water supply management, flood mitigation, ecological sustainability and economic advancement. Using the precipitation and evaporation values of the Ömerli Dam basin in Istanbul, which affect the dam's water level, along with the dam's water level measurements from 2000 to 2023, the aim was to predict the water level in the dam reservoir for the first 15 days of March 2023 using artificial neural networks. In the models created with artificial neural networks, monthly datasets obtained from ISKI's daily data were used with the multilayer artificial neural network model LSTM. The proposed model features a three-layer LSTM architecture with 64 hidden units in each layer and a fully connected output layer. A sliding window method was applied to generate input sequences based on a 30-day historical look-back. The training process utilized the Adam optimizer and mean squared error (MSE) as the loss function. Early stopping was integrated to mitigate overfitting and enhance model generalization. It was determined that the predicted data closely matched the actual water level, with an RMSE value of 62.33, while the R^2 score of 0.9679 demonstrates the model's ability to explain 96.79% of the variance in water levels. Both training and validation phases confirmed the consistency and reliability of the predictions. Based on these results, it can be stated that the ANN model provides successful outcomes in predicting the water level of the Ömerli Dam.

Keywords: Artificial Neural Networks, Dam Water Level, Prediction, Precipitation, Evaporation.

Introduction

In recent decades, the accurate prediction of reservoir water levels has become increasingly critical due to the escalating effects of climate change, irregular precipitation patterns, and rising water demands in urban environments. Effective forecasting of reservoir levels is essential not only for optimizing water resource management and infrastructure planning, but also for mitigating risks associated with extreme hydrological events such as droughts and floods. Conventional statistical methods often fall short in addressing the nonlinear and dynamic behavior of hydrological systems. In contrast, data-driven approaches, particularly deep learning models, have shown significant promise in capturing the complex temporal dependencies inherent in such systems.

Long Short-Term Memory (LSTM) networks, a type of recurrent neural network, have emerged as a powerful tool for time series forecasting owing to their ability to learn long-range dependencies and retain memory over sequential data. Recent studies have demonstrated the superiority of LSTM models over traditional methods in water level forecasting tasks. For instance, Vizi et al. applied the LSTM model to the Tisza River in Central

Europe, reporting high accuracy in both low (≤239 cm) and flood (≥650 cm) water levels, although with moderate reliability at intermediate levels (1). Their findings underscore LSTM's strength in dealing with extreme hydrological conditions.

Similarly, Özer et al. compared LSTM with other machine learning models for predicting water levels in Mamasin Reservoir. The LSTM model achieved outstanding performance, with $R^2 = 0.9515$ and RMSE = 3.49, indicating its robustness and reliability (2). A hybrid LSTM–GRU model was proposed by Cho et al., incorporating meteorological inputs and achieving high accuracy metrics (MSE = 3.92, NSE = 0.942, MAE = 2.22), particularly in flood prediction scenarios (3). These findings suggest that combining LSTM with other deep learning architectures can further enhance model performance.

Expanding on this trend, Li et al. evaluated several LSTM-based hybrid models including BiLSTM, CNN–LSTM, and CNN–Attention–LSTM for the Three Gorges Reservoir. Their results highlighted the CNN–Attention–LSTM model's superior ability to capture both seasonal variations and short-term fluctuations, emphasizing the potential of hybrid deep learning models for improving forecast accuracy in complex hydrological environments(4).

Building upon these advancements, this study presents a data-driven approach to forecast the monthly water level of the Ömerli Reservoir using an LSTM neural network. The model leverages LSTM's temporal learning capabilities to process daily reservoir data and generate multi-step ahead predictions. The workflow includes comprehensive data preprocessing, model training and evaluation, and visualization of forecast results. Model performance is assessed using Root Mean Square Error (RMSE), providing a quantitative measure of prediction accuracy. This research not only contributes to the growing body of literature on deep learning applications in hydrology but also offers practical insights for sustainable reservoir operation and water resource management.

Methodology

In this study, a deep learning-based LSTM (Long Short-Term Memory) model was developed to forecast reservoir water levels using multivariate time series data. The methodology is detailed step by step as follows:

Data preprocessing: The data utilized in this work were obtained from three separate Excel sheets, containing reservoir water levels, precipitation, and evaporation records. These datasets were merged based on date, missing days were filled according to daily frequency, and missing values were imputed using time-based interpolation. A logarithmic transformation was applied to the reservoir water level data to normalize its distribution and reduce the effect of outliers.

Dataset preparation: A sliding window approach was employed to construct input-output sequences for training. The model used the past 30 days of multivariate data as input and predicted the reservoir water level for the next 15 days. The dataset was split into training and validation subsets with an 80/20 ratio.

Model architecture: The proposed model consists of three stacked LSTM layers, each with 64 hidden units. The number of neurons (hidden units) in each LSTM layer is 64.The final layer is a fully connected layer designed to output 15-step multivariate forecasts. To prevent overfitting, a dropout layer with a dropout rate of 10% was included.

Model training: The model was trained using the Mean Squared Error (MSE) loss function, R^2 and the Adam optimizer with a learning rate of 0.001 and weight decay of 1e-5. An early stopping mechanism was implemented, terminating training if the validation loss did not improve for 10 consecutive epochs.

Prediction and evaluation: After training, the model weights with the best validation performance were used for testing. Using the most recent 30 days of data, forecasts for the next 15 days were generated and inverse transformed back to the original scale. Model performance was evaluated using the Root Mean Squared Error (RMSE), R^2 between the actual and predicted values.

Visualization: The actual, predicted, and future forecasted values were visualized on a time series plot. Additionally, the training and validation loss curves were plotted to show the model's convergence over epochs.

Main Results

In Figure 1. it can be see that the training and testing correlation values of the artificial neural network are close to each other and close to zero.

In Figure 2. it can be seen that the values predicted by the ANN overlap with the observed values in some parts of the graph, while in other parts they fall slightly below or above the actual values. This indicates that the model has a low error margin.

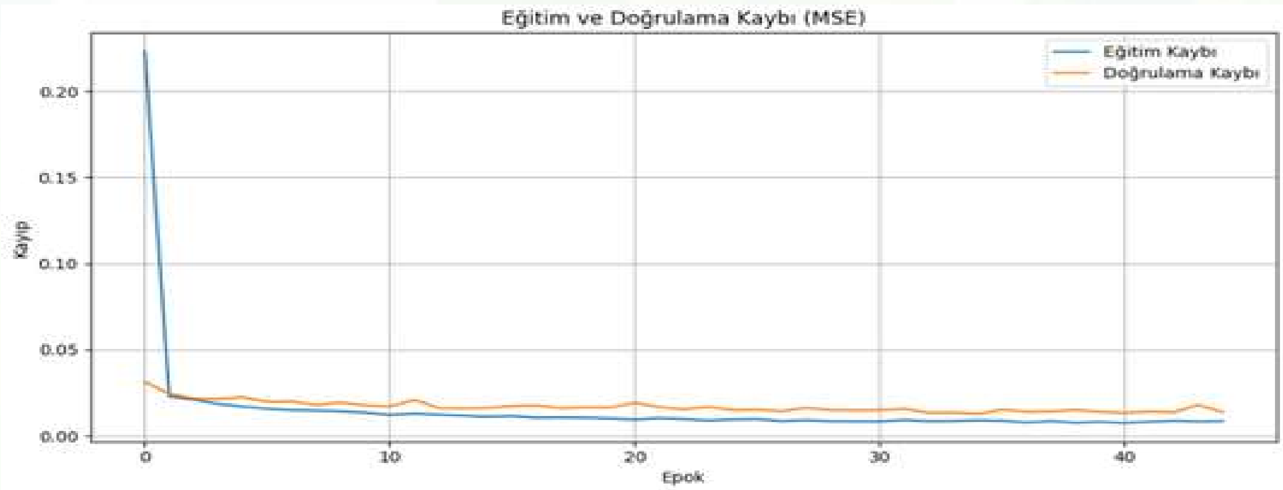

Figure1. Loss of training and test correlation and R^2 score.

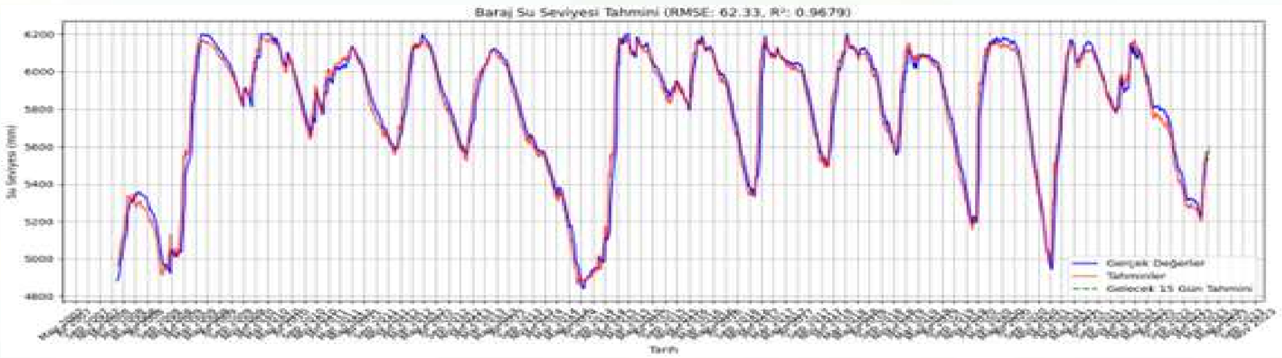

Figure 2. Graph of the distribution of and actual values by month.

Conclusion

In this study, an LSTM-based deep learning model was developed to forecast daily reservoir water levels using meteorological and hydrological variables such as rainfall and evaporation. The dataset, compiled from three different sources, was preprocessed by interpolating missing values, applying logarithmic transformation to reduce skewness, and standardizing features using a StandardScaler.

The model architecture consists of a three-layer LSTM with 64 hidden units per layer and a fully connected output layer, trained to predict water levels for the next 15 days. A sliding window approach was used to create sequences with a 30-day look-back period. The model was trained using the Adam optimizer and mean squared error (MSE) as the loss function, with early stopping implemented to prevent overfitting.

Evaluation on the validation dataset showed a good match between predicted and actual values, with a final RMSE that reflects strong forecasting performance. Additionally, visualizations of past predictions and future projections illustrate the model's ability to capture temporal trends and provide actionable insights. In this study, the obtained R^2 score of 0.9679 indicates that the model performs with high accuracy in predicting reservoir water levels. R^2 was used during both the training and validation processes, and it was also calculated to evaluate how accurately the model predicts based on historical data. This value shows that the model successfully explains approximately 96.79% of the variations in water levels and is capable of generating reliable forecasts.

This LSTM-based forecasting framework can serve as a valuable decision-support tool for water resource management, enabling proactive planning against potential shortages or overflows.

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Typo-morphological Reflections of New Generation Urban Living Spaces in Rural Contexts: The Case of Kalabak

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ABSTRACT

Urbanization processes significantly influence not only metropolitan areas but also the surrounding rural settlements. With the increasing impact of urbanization on rural areas in Turkey, new legal regulations have been required for the governance and planning of these areas. In this context, Law No. 6360, which came into force in 2012, reclassified villages and towns within the administrative boundaries of metropolitan municipalities as neighborhoods (Official Gazette, 2012)[1]. Although this regulation aimed to sustain rural life, hybrid transitional zones have emerged where spatial structures are transformed, everyday life practices shift, and cultural disintegration deepens in peri-urban areas. In such transitional zones, the replacement of traditional housing forms with new types threatens the continuity of local spatial identities. The lack of systematic data on housing typologies and spatial patterns, along with the limited academic literature on the rural neighborhoods of Aliağa—a district of İzmir province—prompted the selection of Kalabak Neighborhood as the case study. The samples within Kalabak were selected through stratified sampling to represent the diverse spatial and morphological characteristics of Aliağa's rural fabric. This study examines spatial data in Kalabak through a tipo-morphological framework developed based on Conzen's urban plan analysis (1960)[2] and the urban evolution theory of Caniggia and Maffei (2001)[3], utilizing field observations, demographic data, and Geographic Information Systems (GIS). The analysis was conducted based on categories and sub-parameters defined within the tipo-morphological approach to investigate the physical-spatial structure of Kalabak Neighborhood. The parameters used were derived from fundamental approaches commonly applied in the urban morphology literature[4-14]. This research constitutes an initial step in the documentation and interpretation of rural morphological typologies in Aliağa, contributing to the understanding of how spatial identity in rural areas evolves under administrative and socio-economic influences.

Key words: typo-morphology, rural settlements, housing typology, spatial analysis

Introduction

Today, rural areas are no longer solely defined as zones of agricultural production; rather, their increasing interaction with urban environments has led to significant transformations in spatial identity, building patterns, and socio-cultural organization. In particular, the transplantation of urban lifestyle practices into rural contexts has accelerated the transformation of traditional settlement structures and housing typologies. This process necessitates not only a functional but also a formal and morphological reassessment of rural settlements.

Typo-morphology first gained prominence in the 1950s through Muratori's[15] conceptualization of the "typological process" in Italy, and was further developed theoretically by Caniggia and Maffei (2001)[3]. Conzen (1960)[2], through his work in England, emphasized the significance of historical spatial continuity. Moudon (1997)[16] and Madanipour (2001)[17] expanded this approach to include social functions and multi-scalar spatial organization. Additionally, studies led by Panerai, Castex, and Depaule (2004)[18] in France revealed that the transformation of urban form is shaped not only by physical and spatial components but also by social, historical, and cultural dynamics.

In this context, the study first examines key analysis parameters frequently employed in urban morphology literature, classifying the typological and morphological criteria proposed by Caniggia and Maffei and Conzen within a shared theoretical framework. Based on this framework, the field research conducted in Kalabak Neighborhood documents and analyzes housing typologies, parcel configurations, and street patterns. The findings indicate that while the spatial structures of rural settlements largely retain their traditional characteristics, they also exhibit formal divergence due to recent building trends. These insights provide valuable guidance for the development of planning and design policies aimed at preserving rural identity.

This study adopts a typo-morphological approach to identify and interpret the spatial characteristics of rural settlements in the Aliağa district. Focusing specifically on Kalabak Neighborhood, it aims to build a scientific foundation for rural identity-sensitive planning through the documentation and analysis of existing housing typologies and spatial forms.

The primary aim of this study is to identify the morphological patterns and document the elements of rural spatial identity by examining the spatial and housing typologies of Kalabak Neighborhood. Kalabak was selected due to its representational significance and the lack of prior academic research on the area. The study seeks to develop a detailed morphological profile through qualitative field observations and spatial data modeling.

The geographical scope is limited solely to Kalabak Neighborhood, located within the district of Aliağa. The absence of current and systematic datasets detailing the spatial layout and housing typologies of this neighborhood, along with the lack of original academic studies on Aliağa's rural settlement structure, have been decisive in selecting this area as the focus of the research. Accordingly, the study aims to fill a gap in the literature and provide an original contribution.

Methodology

This study was conducted using a mixed-methods approach that combines qualitative and quantitative data collection techniques, focusing on the morphological analysis of rural housing typologies. Qualitative methods such as field observation, documentation, and user interviews were supported by quantitative techniques including building measurements, mapping, and technical drawing. This methodological approach allowed for a holistic evaluation of both the physical characteristics of the built environment and its broader contextual relationships.
Data were obtained from both primary and secondary sources. Primary data were collected through on-site observations, photography, measurements, and analysis of architectural documents conducted during fieldwork. Secondary data were gathered from written and visual materials such as literature reviews, land registry records, zoning plans, and satellite imagery. Special emphasis was placed on in-situ documentation of buildings and the generation of accurate drawings throughout the data collection process.
The data used in this study were obtained from official institutions such as the Turkish Statistical Institute (TÜİK)[19], Aliağa Municipality[20], local neighborhood administrations, the Directorate of National Real Estate[21], and the General Directorate of Land Registry and Cadastre[22]. Maps, plans, and visuals used in the field study

were prepared and analyzed using NetCAD, AutoCAD, and Photoshop software. During the data collection process, particular attention was paid to ensuring that the planning documents, demographic data, social infrastructure information, and physical-spatial datasets related to the Aliağa district were current, accurate, and contextually appropriate. This ensured a comprehensive correlation between observational data obtained through fieldwork and institutional data, thereby increasing the reliability of the spatial analyses.
The research methodology was structured based on the intersection of morphological analysis approaches developed by the Caniggia and Conzen schools. Accordingly, a multi-layered analysis model was developed encompassing physical, environmental, economic, demographic, and social infrastructure components. Within this framework, the spatial analyses conducted in the study area were carried out based on the following morphological parameters:

1. Settlement Pattern
2. Transportation Network
3. Density & Open Space
4. Architectural Style
5. Openings & Roof Forms
6. Vertical Profile
7. Plot- Buildings Relationships
8. Building Orientation
9. Demographic Structure

Main Results and Discussion

Aliağa, a district of İzmir province, comprises a total of 32 neighborhoods, 19 of which are classified as rural. Kalabak Neighborhood is a rural settlement located in the northeastern part of the district. It is situated 19 km from the district center and 79 km from the provincial center. The total area of the neighborhood is 19.1 km², with a population of 384 as of 2023[19]. There are two distinct settlement units within Kalabak Neighborhood: “Eski Kalabak” and “Yeni Kalabak,” the latter of which emerged in 2020 through a formal parceling process. These two areas are connected by a 7.7 km stretch. Spatial, demographic, and social infrastructure data pertaining to both units are presented in Table 1.

Table 1. General Characteristics of Eski and Yeni Kalabak Neighborhoods

Characteristic	Eski Kalabak	Yeni Kalabak
Population	189	195
Distance to District Center (km)	19.4 km	11.7 km
Sea/Mountain View	Mountain View	Sea View
Settlement Area (m²)	309,189 m²	242,753 m²
Total Number of Buildings	165	104
Number of Derelict Buildings	32	0
Social Facility	None	Available

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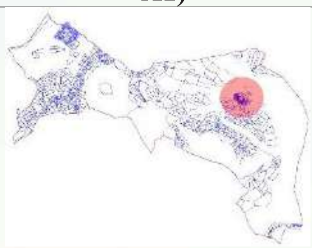
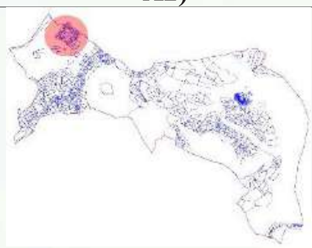
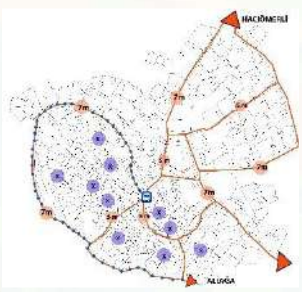
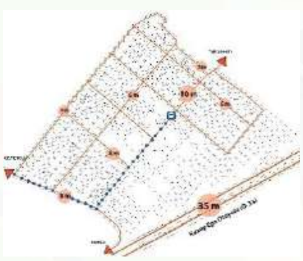
Educational Facility	Available – Closed	Available – Closed
Religious Facility	Available	Available
Green Space	Available	Available
Sports Facility	None	Available
Sample Area (m²)	10,179 m²	22,050 m²

Despite Eski Kalabak having a relatively large settlement area of 309,189 m², it is noteworthy that 19% of its buildings are in a derelict condition. This indicates a gradual loss of function in the physical environment and suggests a disruption in spatial continuity. In contrast, the fact that all buildings in Yeni Kalabak are in active use demonstrates the impact of planned development on physical sustainability.

From a social infrastructure perspective, the presence of facilities such as sports and community centers in Yeni Kalabak highlights the contribution of planned development to social life. The absence of such amenities in Eski Kalabak reflects the limited access to communal spaces in traditional rural settlements. Furthermore, Yeni Kalabak's shorter distance to the district center (11.7 km) and its scenic sea view may help explain the increasing preference for rural living in recent years. Conversely, Eski Kalabak's mountain view represents a more inward-looking and traditional rural character.

Accordingly, the comparative analysis of morphological characteristics in the two settlement units is presented in Figures 1 and 2, revealing significant differences in terms of spatial structure, transportation layout, and architectural preferences.

Analysis Titles	**Eski Kalabak (Sample A1)**	**Yeni Kalabak (Sample A2)**	**Representation**
Settlement Areas			Settlement
Transportation & Accessibility			Village Internal Transportation Road Width Cul-de-sac Public Transportation Stop

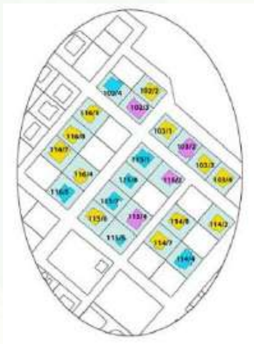
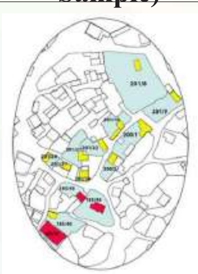
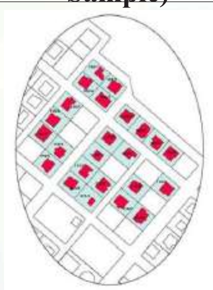
Sample Areas			Sample
Number of Storeys			1 Storeys 2 Storeys 3 Storeys

Figure 1. Morphological Characteristics of the Sample Areas (A1 and A2)

Figure 1 presents a comparative spatial analysis of the sample areas of Eski Kalabak (A1) and Yeni Kalabak (A2). While Eski Kalabak exhibits an organically developed settlement pattern, Yeni Kalabak is characterized by a regular parcel layout. This contrast illustrates the transformation of the irregular built fabric typical of traditional rural villages into a gridded structure in planned development areas.

In terms of internal transportation layout, the road width in both settlement units is approximately 7 meters. However, the presence of cul-de-sacs in Eski Kalabak disrupts spatial continuity, whereas their absence in Yeni Kalabak indicates a more fluid and systematically organized transportation network.

With regard to building height, single-storey structures dominate in Eski Kalabak, while two- and three-storey buildings are more prevalent in Yeni Kalabak. This indicates an increase in both building density and land use intensity in the latter. Moreover, such vertical growth offers a significant clue about the gradual shift of rural areas towards more urbanized spatial forms.

Analysis Titles	Eski Kalabak (A1 Sample)	Yeni Kalabak (A2 Sample)	Representation
Architectural Style			Modern Traditional

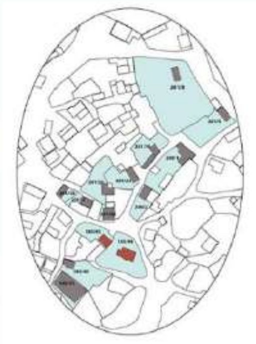
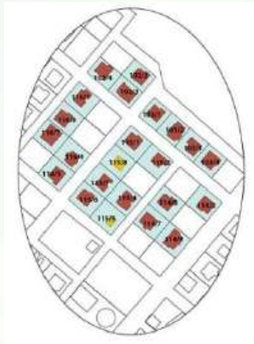
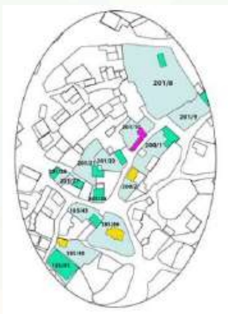
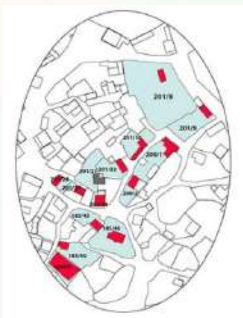
Building Stock			Stone Brick Prefabricated
Door Typology			Iron Steel Wood
Window Typology			Iron Wood PVC
Roof Typology			Tile Teracce Metal Sheet

Figure 2. Comparative Typological Characteristics of the Sample Areas (A1 and A2)

Figure 2 highlights the typological differences in the building stock of both settlement units. In terms of architectural style, traditional structures are predominant in Eski Kalabak, whereas modern buildings dominate in Yeni Kalabak. This contrast reflects the more recent development of Yeni Kalabak and is also evident in the choice of construction materials.

In Eski Kalabak, local and natural materials such as stone and brick are commonly used, while in Yeni Kalabak, prefabricated construction systems have also become prominent. This shift indicates evolving preferences in the building production process, driven by considerations of cost-efficiency and time-saving. Regarding openings such as doors and windows, Eski Kalabak maintains its traditional architectural character through the use of iron and wood, while Yeni Kalabak features more modern materials like steel and PVC. This trend suggests a prioritization of durability and affordability over aesthetic continuity.

When roof typology is examined, tiled roofs are prevalent in Eski Kalabak, whereas Yeni Kalabak exhibits a more diverse typology, including not only tiles but also terrace and metal sheet roofs. This variation points to a growing emphasis on functionality and contemporary construction trends rather than spatial aesthetics. These findings offer valuable insights into the dynamics of spatial continuity and transformation within rural settlements.

Table 2. Comparative Morphological Parameters of Sample Areas A1 and A2

Morphological Parameter	Eski Kalabak (A1)	Yeni Kalabak (A2)
Settlement Pattern	Organic	Gridded
Transportation Network	Includes cul-de-sacs	Fluid, planned
Number of Floors	1–2 storeys	1–2–3 storeys
Architectural Style	Traditional	Modern
Building Materials	Stone, brick	Brick, prefabricated
Door/Window Materials	Iron, wood	Steel, PVC
Roof Typology	Predominantly tiled	Tiles, terraces, metal sheets
Social Infrastructure	Limited	Developed
Occupancy Status	19% abandoned	100% in use

The comparative table above highlights the fundamental morphological contrasts between Eski Kalabak and Yeni Kalabak. While Eski Kalabak retains the organic and traditional features typical of historical rural settlements, Yeni Kalabak exhibits a more modern and planned urban form. These differences underline the dual nature of spatial transformation in peri-rural areas, shaped by administrative restructuring, socio-economic trends, and evolving construction practices.

Conclusion

This study analyzed the relationship between spatial continuity and morphological transformation in rural areas, revealing how the traditional settlement fabric of Kalabak Neighborhood interacts with contemporary building dynamics. The findings reaffirm the necessity of evaluating rural settlements not only in terms of functionality but also through their formal, cultural, and morphological characteristics.

The research indicates that the disregard of traditional typological features—such as façades, materials, and roof types—in new developments leads to a loss of spatial identity and the disruption of morphological integrity. In this context, it is recommended that typo-morphological analyses be utilized as guiding tools in planning and construction processes in rural contexts.

For future studies and practical implementations, attention should be given to the following aspects to ensure the preservation and continued vitality of rural heritage:

- Development of building guides that reference local architectural identity,
- Formulation of construction principles compatible with the traditional fabric,
- Integration of typo-morphological analysis into zoning and development plans,
- Establishment of incentive mechanisms for the preservation and restoration of existing buildings,
- Adaptation of architectural control mechanisms to the specific characteristics of rural contexts,
- Regulation of new developments in ways that do not disrupt morphological continuity,
- Incorporation of formal coherence alongside functional considerations in planning decisions,
- Definition of licensing procedures sensitive to traditional construction techniques,
- Avoidance of physical interventions that exclude local lifestyles and cultural context.

In conclusion, a planning approach that focuses on enhancement rather than transformation, and one that preserves the authenticity of rural space, should be adopted. This would not only improve the quality of life in rural areas but also ensure the sustainability of their spatial identity.

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Navigating Socio-Economic Conditions, Governance Structures, and Cultural Values for Adopting Smart City Technologies in the Global South: Evidence from Youths in Kampala, Uganda

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ABSTRACT

The adoption of smart city technologies in the Global South presents unique opportunities and challenges shaped by diverse socio-economic conditions, governance structures, and cultural values. In this study, the contextual factors that influence the participation of youth in the adaptation of smart city technologies in Kampala, Uganda, were examined. The research survey data highlights that youth in Kampala face key barriers such as digital illiteracy, high costs of devices and internet access, institutional exclusion, and the cultural misalignment of technologies. The finding further indicates that though Kampala being the most connected demographic, youth in Kampala are not engaged in smart city planning and decision-making processes. The study thus recommends an urgent need for inclusive policies and investments that target digital infrastructure, education, and youth-centered governance. Services such as affordable internet, digital learning platforms, and job-matching apps are top priorities for youth's desire for smart technologies that directly address employment, education, and connectivity needs. This research contributes to a deeper understanding of how smart city initiatives can be made more equitable and locally relevant by centering the voices and needs of youth in urban innovation agendas.

Key words: Smart City Adoption, Youth Participation, Global South, Socio-Economic Challenges, Governance and Technology.

Introduction

A Smart City is a system of systems, involving the symbiotic linkage among people, institution, technology, organization, built environment, and physical infrastructure. Smart city technologies encompass digital tools, such as Internet of Things (IoT) devices, artificial intelligence (AI), and data analytics, aimed at enhancing urban management and quality of life (1). In this context, six dimensions of smart cities are outlined; i.e. smart economy mainly driven by industry, smart governance focusing on e-democracy, smart living dealing with security and quality of life, smart mobility deals with infrastructure and logistics, smart people relating to education and literacy levels, and smart environment concerned with efficiency and sustainability. These six dimension have provided a framework to analyze urban development holistically (1). However, of the six dimensions most Smart City initiatives frequently focus on smart environment and smart mobility with less attention on the other four dimensions. Other studies such as (2) have mentioned four dimensions of smart cites, i.e. application of a wide range of electronic and digital technologies to create a cyber, digital, wired and informational or knowledge-based city; the second is the use of information technology to transform life and work; the third is to embed ICT in the city infrastructure; the fourth is to bring ICT and people together to enhance innovation, learning, and knowledge. This concept of smart cities has become increasingly prominent in urban development, particularly in the Global North, where technologies like Internet of Things (IoT) devices, big data analytics, and artificial intelligence (AI) have transformed urban planning and management. In the Global South, however, implementing these technologies may require adaptation to local contexts due to resource constraints and informal urban systems prevalent in developing regions (3). Thus, this warrants context-specific solutions over universal models typically implemented in the Global North.

The diverse socio-economic landscape and cultural contexts of the Global South presents various governance challenges. With benefits such as increased citizen engagement, better delivery of services and improved economic growth offered by smart city technologies, if not adapted to local needs, associated risks may arise because of widening inequalities (4). Population growth is driving rapid urbanization in these regions and thus inclusive urban development is critical. To avoid deepening existing needs, thoughtful implementation of smart technologies is critical to empower marginalized communities. Widespread poverty, informal economies and inadequacies in infrastructure which majorly characterize the socio-economic context of the Global South limits the effective implementation of smart city technologies (5). Taking for example smart transportation systems that depend on widespread technology and reliable public transits are very much larking. Many residents lack device or internet access or both which creates a digital divide and thus becoming a significant barrier to implementing smart city technologies (6). To effectively implement smart city technologies in the Global South, smart city initiatives must not widen this gap, but prioritize on closing it to make sure that there is equitable benefit. Government agencies, private sector and civil societies in the Global South often work with limited coordination, this creates fragmented governance structures (7). These fragmented governance structures complicate not policy development, but also integration of technology, which is key to implementing smart city initiatives. Lack of transparency, corruption and limited institutional capacity further exacerbate the problem (8). In many cities in the Global South, smart city technologies have been misused for political gain instead of benefiting the public. Therefore, effective implementation of smart city technologies requires collaborative governance and diverse stakeholder engagement. The way smart city technologies are perceived in the Global South is significantly shaped by cultural values and social norms. Many communities rely on informal networks, and smart city technologies must align with these structures to be effective (9). Technology is perceived as intrusive or empowering across many cultures. Some cultures perceive smart technologies with skepticism due to surveillance concerns (10). To build trust and ensure smart city technology acceptance, culturally sensitive engagement is crucial. Therefore, in the Global South, a comprehensive yet holistic approach to smart city initiatives requires moving beyond one-size-fits-all solutions. This should include participatory design that engages local communities in developing smart city technology solutions, that enhance relevance and acceptability (11). If local knowledge is leveraged, it can lead to context-specific and sustainable smart city solutions that address the unique needs of each urban setting. In the Global South, the urban population is expected to be 60% composed of youth by 2030 (12). This makes youth key stakeholders in making sustainable choices as 83% of the youth in the Global South are already knowledgeable about waste management, 74% prioritize energy reduction and 71% are in favor of online shopping (13). therefore, the participation of youth in smart city initiatives is vital. As primary internet users, they engage in education, job searches, and civic activities, aligning with smart city goals (14). However, exclusion from planning, lack of trust in governments, and limited climate education hinder their involvement (15). Strategies like environmental education, transparency, and incentives for youth-led initiatives can foster their participation (16). Engaging youth in smart city planning taps into their creativity and commitment to sustainability, ensuring urban development meets current and future needs. The future of urban living in the Global South hinges on integrating innovation with inclusivity, particularly by empowering youth to shape their cities.

The core research question this study aimed to explore was: “In what ways do socio-economic factors, governance frameworks, and cultural beliefs impact the acceptance and utilization of smart city technologies by young people? Specifically, the study focused on the following questions:

i. How do economic status, education, and access to digital infrastructure affect the ability of youth to adopt and use smart city technologies?
ii. How do government policies, leadership, transparency, and youth participation influence both the perceptions and adoption of smart city technologies among youth?
iii. How do cultural beliefs, traditions, community values, and social norms shape youth attitudes and adoption of smart city technologies?

Thus, the study sought to investigate the adaptation of smart city technologies in the Global South by addressing both opportunities and challenges for inclusive participation of youth in urban development.

By navigating the complex interplay of socio-economic conditions, governance structures, and cultural values; policymakers and urban planners can develop strategies that not only harness the potential of technology but also promote equity, participation, and sustainability. The imperative for inclusive urban development in the face of rapid urbanization and socio-economic disparities cannot be overstated; as such, a critical examination of the ways in which smart technologies can be adapted to serve the needs of youths is essential. The future of urban living in the Global South depends on the ability to thoughtfully integrate innovation with inclusivity, ensuring that the promise of smart cities is realized for all.

Various studies stress the importance of adaptable frameworks for smart city development. Point in case, (17) enhance socio-technical strategies that blend technology with human -focused urban planning, certifying applicability across multiple Global South contexts. These views highlight the essentiality of customizing smart city technologies to take forward local infrastructure shortages and socio-economic conditions.

According to (18), over one billion people live in non-standard settlements without access to crucial needs like water and electricity, which complicates the rollout of tech-reliant smart systems. As noted in (19), smart city initiatives must concentrate on social equity to avert widening inequalities, pushing for infrastructure investments that boost marginalized groups. Socio-economic disparities often challenge smart city projects in the Global South (20), promoting the need for inclusive policies to assure fair access to technology and its advantages. These insights suggest that smart city strategies in the Global South should emphasize equitable access to technology and resources to drive inclusive urban growth.

Effective governance is evaluative for smart city success, yet Global South cities frequently face stumbling blocks like corruption, limited transparency, and weak institutional frameworks. The advantage of strong governance systems to guide smart city transitions is underscored in (21), with focus on accountability metrics and stakeholder cooperation. Participatory governance models are attaining support, with (22) displaying that involving citizens in decision making amplifies project legitimacy and impact. Collaborative governance is also on an increasing rate for example, (23) demonstrates how the system dynamics modelling nourishes collaborative governance in smart cities, using Dongguan -China as a case study to highlight the value of aligning policies among government, private sectors and citizens. These principles of multi-stake holder collaboration are appropriate to other Global South cities, where inclusive governance can address institutional weakness.

Cultural values play a remarkable role in shaping the acceptance of smart city technologies in the diverse urban settings of the GLOBAL South Cultural resilience, as noted in (24), is a necessary factor that enables communities to integrate local heritage and knowledge into smart city initiatives, certifying that technologies align with community identities and encouraging adoption. Community engagement is key for project success. According to (25), inclusive planning that prioritizes resident input builds trust and certifies smart city projects meet local needs.

Similarly, a 2025 study on Sao Paulo and Berlin by (26) intensifies the role of ethical AI and participatory platforms in stimulating social inclusion, displaying that culturally sensitive technology can build-up civic engagement. These findings highlight the need for human centered urbanization that balances technological advancement with cultural diversity.

The latest case studies shed light on both successes and bottlenecks in Global South smart city projects. In Seoul and Ho Chi Minh City, (27) elaborate how integrated transit service platforms refined accessibility and equity, driven by robust government action and public-private patronships. This indicates the potential of integrated smart interventions to address socio- economic challenges. However, India's smart cities mission unveils pitfalls of top-down approaches that may neglect local needs, risking deeper inequalities (28). While the mission's basis on sustainability and citizen participation is encouraging, critiques call for stronger grassroots engagement. These examples underscore the need for context-specific strategies that prioritize inclusivity and local governance capacity. Summing up all, deploying smart city technologies in the Global South requires a nuanced approach that accounts for socio-economic disparities, governance challenges, and cultural diversity. The literature advocates for inclusive urban development through equitable resource allocation, participatory governance, and culturally attuned community engagement. As urbanization intensifies, further research is needed to craft innovative, context-specific strategies that harness smart technologies for sustainable and inclusive urban futures in the Global South.

Methodology

The study followed a cross-sectional research design. It used qualitative data that was collected using a survey questionnaire. The questionnaire was designed using google forms and followed a five-point (1-5) Likert scale i.e. Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree. The survey questionnaire focused on three major themes; the first theme was on the socio-economic status of the youth, second was governance structures and the third theme was on how smart city technologies address the cultural values. However, respondents were also asked on their level of awareness and use of smart city technologies, the priorities for smart city services and the preferences and recommendations for the implementation of smart city projects. For easy reach to the respondents, the survey questionnaire was distributed to respondents via social media community platforms and networks. Prior to filling the questionnaire, informed consent of the participants was sought only those who consented were able to fill in the survey questionnaire. Moreso, Confidentiality and anonymity were maintained as no personally identifiable data was collected nor stored. The data collection took a period of three weeks. In this period, a total of 183 participants were able to respond to the survey questionnaire. The qualitative nature of the data collected was descriptively analyzed using numpy and pandas python libraries.

Main Results and Discussion

This section gives an overview of the demographic analysis of participants in a study to explore different opinions about smart city technologies in Kampala, Uganda. The research points out different demographic characteristics such as gender, education levels, age, employment status, income level to understand their influence on factors such as socio-economic conditions including living standards, financial stability, political conditions like governance, leadership structures, and cultural-preferences that shape the adoption of smart city technologies among youth in Global South.

The age demographics shows that most respondents are youths, with 56.9% between 18-24 years old. This highlights how much the younger generation is interested in smart city technologies. Participants aged 25 to 30 comprised 27.3% while individuals above 30 made up 15.3%. Only 1.1% were under 18. Many respondents are between 18 and 30, which means they are likely comfortable with technology and open to new ideas. This matches a global trend where young people are getting more involved in discussions about city development and technology.

Based on gender, the group almost had the same number of men and women, with 43.6% female and 56.4% male. This shows the different roles men and women have in Uganda and how they impact the socio - economy activities. Having almost equal numbers of men and women offers a better understanding of how both genders think about and use smart city technologies. Including different gender opinions is important so as to recognize how governance and cultural factors influence technology adoption. On the education level, the results show that 1.6% had completed primary school, 18.6% secondary, 9.3% had certificate of diploma, 59.0% had completed bachelor's degree and 11.5% were postgraduates. This means that the sample is highly educated, with 70.5% holding a diploma or higher qualification, reflecting an informed and potentially tech-literate group. This level of education aligns with the ability to critically assess policy, socio-economic structures, and cultural dynamics that affect smart city implementation. It also implies a readiness among Kampala's educated youth to engage with smart systems (e.g., e-governance, urban data, digital payments), but their capacity to do so may still be constrained by structural limitations such as affordability or governance inefficiencies. The employment status of respondents further contextualizes their socio-economic conditions. A significant majority, 55.7%, identified as students, which indicates that a large portion of the youth population is still in the educational system. This status may impact their perspectives on smart city technologies, as students are likely to have different priorities and concerns compared to those who are employed or unemployed. Among the respondents, 39.9% were employed, while 4.4% were unemployed. The relatively high percentage of students reflects the importance of educational institutions as platforms for fostering awareness and engagement with smart city technologies. Conversely, the employment status of respondents raises questions about job opportunities and the role of governance structures in facilitating youth employment within the context of smart city initiatives. The demographic composition of the sample strongly supports the study's focus on navigating smart city adoption in the Global South through the lens of youth in Kampala. The data reflects a well-informed, urban-based, and largely optimistic generation that is grappling with socio-economic realities, governance challenges, and cultural shifts. Their collective voice underscores the importance of inclusive urban planning, where smart technologies are not only introduced but are made accessible, relevant, and equitable, especially to the growing youth population that will shape Africa's urban future.

In this section of the results, the findings of the survey on perceptions regarding awareness and use of smart city technologies, socio-economic conditions, governance structures, and cultural values are presented. The data collected from respondents was analyzed to determine the distribution of opinions across various dimensions, as outlined in the survey. The results are summarized in percentage form, reflecting the degree of agreement or disagreement with each statement related to the aforementioned themes. The findings are presented in Table 1.

Table 1. Aggregated Percentage responses on the items in the survey questionnaire

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Awareness and use of smart city Technologies	14.5	14.3	19.8	29.5	21.9

Socio-economic conditions	8.3	12.6	19.5	29.3	30.3
Governance structures	8.2	12.9	18.4	31.4	29.1
Cultural Values	7.2	11.4	25.7	31.3	24.4

Awareness and Use of Smart City Technologies

The survey revealed varied levels of awareness and utilization of smart city technologies among respondents. As depicted in Table 1, 14.5% of participants strongly disagreed with the statement regarding their awareness and use of smart city technologies, while 14.3% disagreed. This indicates a significant portion of the population that does not recognize or engage with these technologies. Conversely, a combined 51.4% of respondents either agreed (29.5%) or strongly agreed (21.9%) that they were aware of and utilized smart city technologies.

The findings reflect a generally favourable view of smart city initiatives among most participants. However, with 19.8% of respondents expressing neutral attitudes, it's clear that a significant portion remains indifferent about their awareness and usage of these technologies. This highlights a divide in perception while many individuals recognize and actively engage with smart city solutions, a notable group either lacks awareness or has yet to adopt them. This suggests a valuable opportunity to boost education and outreach efforts aimed at those currently disengaged.

Socio-Economic Conditions

Insights from the survey underscore the complex influence of socio-economic factors on how individuals perceive and interact with smart city technologies. According to Table 1, only 8.3% of participants strongly rejected the idea that their socio-economic status affects their engagement with these innovations, with an additional 12.6% expressing disagreement. However, a more significant portion of respondents, 29.3%, agreed, and 30.3% strongly agreed that socio-economic conditions play a crucial role in their interactions with smart city technologies. The neutral response rate was 19.5%, indicating that a significant number of respondents are unsure about the impact of socio-economic factors on their engagement. These results underscore the importance of socio-economic conditions in shaping perceptions and interactions with smart city technologies. The fact that over half of the participants acknowledge the influence of these conditions suggests that policymakers and urban planners should consider socio-economic disparities when designing and implementing smart city initiatives. If these disparities are addressed, cities can enhance the effectiveness and inclusivity of their technology deployments especially among youth.

Governance Structures

The survey also assessed the governance frame works championing smart city technologies. As displayed in table1,only 8.2% of the respondents strongly disagreed with the statement about the effectiveness of governance structures in advancing smart city initiatives , while 12.9% disagreed conversely , a notable 31.4% agreed , and 29.1% strongly agreed that governance structures are critical for successfully implementing smart city technologies .Meanwhile ,18.4% of the respondents remained neutral, suggesting some uncertainty about the efficacy of these governance systems .These findings giveback a widespread belief among most respondents in the advantages of robust governance for effective smart city technology deployment .This underscores the need for transparent ,accountable , and inclusive governance models to build public trust and participation .In addition, the notable neutral response rate points to a need for greater education and communication about existing governance structures and their roles in smart city.

Cultural Values

The research also looked at how cultural values shape people's views on smart city technologies. Table 1 shows that 7.2% strongly disagreed and 11.4% disagreed that culture affects their opinions. Meanwhile,31.3% agreed and 24.4% strongly agreed that cultural beliefs are important in their involvement with smart city projects. About 25.7% were neutral, meaning they were unsure or didn't have a clear opinion on this. These results show that cultural values play an important role in how people feel about and take part in smart city projects. Many respondents who agreed highlight the need to include cultural factors when planning and building smart city initiatives. If cultural values are acknowledged and respected, urban planners and policymakers can enhance the acceptance and effectiveness of smart city technologies within diverse communities.
Figure 1 shows the many interrelated challenges that youth in Kampala face in adapting to smart city technologies. The major challenge is lack of awareness of smart city technologies among citizens in general and digital literacy. This greatly limits not only their understanding but also engagement with smart city technologies. The high cost of smart devices and internet services was cited to further restrict access, especially for low-income youth. A number of institutional constraints such as poor governance, limited coordination, and exclusion of youth from policy-making processes were also cited as hinderances to the development of inclusive digital strategies. On the cultural side, many technologies are not contextually adapted, making them less accessible or relevant to local users and this further marginalizes the youth in the smart city transformation. Addressing these challenges requires multi-stakeholder collaboration focused on affordability, digital literacy, inclusive governance, and culturally contextualizing technology design

Figure 1. Challenges youth in Kampala face in adopting smart city technologies.

Prioritization of Smart City Services

In this last section of the results, we present the findings derived from the survey conducted among youths in Kampala, Uganda, regarding their preferences and perceived priorities for the adoption of smart city technologies. The findings are shown in Table 2 below.

Table 2. The services that should be prioritized for smart city

Services that should be prioritized	% respondents
Affordable internet access	79.2

Jobs and skill matching mobile apps	68.9
Digital learning platforms	68.3
Digital health care services	48.1
Online access to government services	45.9
Smart transportation and traffic management	41.5
Public safety technologies	40.4
Renewable energy solutions	32.2

The results indicate a clear hierarchy of preferences among the respondents concerning which smart city services should be prioritized. The data reveals that affordable internet access is overwhelmingly viewed as the most critical service, with 79.2% of respondents emphasizing its importance. This finding aligns with the understanding that digital connectivity is foundational for the effective implementation of other smart city technologies. In a context where many youths rely on mobile devices for information, education, and communication, the demand for affordable internet is both a reflection of current socio-economic conditions and a prerequisite for digital empowerment. Ranked second was job and skill matching mobile applications at 68.9%. This is attributed to the fact that many responds were students who are looking forward to employment after school and those who are unemployed. Thus, the respondents felt that job matching can be facilitated by technology. At 68.3% were digital learning platforms. Having gone through the COVID-19 period without being at school, the youth in Kampala feel that their education should not be disrupted that much and at the same time should be flexible and innovative. Thus, the preference of digital learning platforms as bridges to traditional learning environments. In the fourth position was digital healthcare services. This is due to the limited access to medical services which results into long waiting times. This means that youth understand that technology can be used to enhance healthcare delivery, facilitate access to essential services and greatly improve doctor-patient engagements. Youth feel that they need to participate in e-governance and thus they ranked access to online government services fifth. This finding reveals that youth yearn for accessibility, efficiency, and transparency in government-citizen interactions. This would greatly enhance civic engagement and accountability. Like many cities in the Global South, Kampala' public transportation infrastructure is wanting and suffers traffic congestion. Thus, youth ranked smart transportation and traffic management among the top smart city services at 41.5%. With smart transportation and traffic management, improved traffic flow and public transport can be achieved. Public safety technologies garnered the support of 40.4% of respondents. This indicates that in safety is a concern in urban environments. Youth thus believe that technology can play a critical role in crime prevention, emergency response and community safety. Smart city initiatives therefore must prioritize the safety and security of the city's residents. Last on the list of top priorities was renewable energy solutions at 32.2%. Though last on the list, renewable energy highlights an increasing significance of energy sources that are sustainable in the face of climate change and environmental degradation. The youth's interest in renewable energy solutions reflects a commitment to sustainability and the recognition of the potential for technology to support energy efficiency and reduce reliance on fossil fuels. The prioritization of services outlined in this study reveals a complex interplay of needs and expectations among respondents. This underscores the necessity for policymakers, educators, and service providers to collaborate in developing integrated solutions that address these diverse needs.

Figure 2. Youth preferences and recommendations for Smart City Services

The respondents were also asked to give preferences and recommendations for smart city initiatives. The findings are shown in Figure 2. Form the findings, training programs on the use smart city services and digital literacy that are needed to access the smart city technologies was highly recommended. This would equip the youth with the requisite skill set to enable them not only navigate but also contribute to various smart city services. Youth also propose that they should be engaged in smart city creating local solutions through community innovation hubs and in the design of smart city projects. This would make the youth not just users but co-creators of smart city solutions which can be offered easily in local languages. Fostering collaborative frameworks such as private-public partnerships to deliver smart city services was also recommended to ensure relevance and sustainability. Other recommendations were making smart city services cheap and accessible and providing smart city services through mobile instead of web apps. In essence, the result implies that planners should move beyond top-down models and embrace youth-driven, participatory approaches that prioritize capacity-building, inclusion, and innovation to build resilient, responsive, and future-ready cities.

Conclusion

The rapid urbanization and demographic changes in the Global South create both opportunities and challenges for adopting smart city technologies. This research highlights the immediate need for comprehensive approach to smart city development in the regions. The study discloses a complex array of perceptions about smart city technologies and their influencing factor. While most respondents recognizes awareness and use of these technologies , a remarkable portion remains either unaware or disconnected .Socio-economic conditions ,governance frameworks ,and cultural values remarkably shape how people perceive and engage with smart city initiatives .These findings emphasize the need for focused efforts to boost awareness and participation ,especially among underserved communities .Moreover , the critical role of strong governance structures and cultural sensitivity in designing and implementing smart city projects cannot be overstated .

Therefore by understanding the intricate interplay of socio-economic factors ,governance systems and cultural values, policymakers and urban planners can craft strategies that priorities inclusivity and sustainability thereby adopting a holistic , inclusive approach that accounts for these elements permits stakeholder to build smart cities that are technologically advanced, equitable ,sustainable and reflective of diverse community needs and values .Smart city development in the Global South is not just a technological pursuit ,it is fundamentally about improving quality of life for all and stimulate resilient, vibrant urban spaces. Additionally, as cities increasingly embrace smart technologies, establishing frameworks to monitor and evaluate not only technological performance but also socio-economic disparities, governance challenges, and cultural contexts is important, particularly in the Global South.

From the above, metrics should be developed to evaluate the inclusivity of smart city initiatives, ensuring progress is measured not only by efficiency but also by enhanced quality of life for all residents. Through inclusive and participatory approaches, cities can leverage these technologies to boost equitable urban development and strengthen urban resilience amid rapid change. Therefore, future research should explore innovative models and the best practices to advance inclusivity and sustainability, contributing to an extensive conversation on 21st-century urban development. Investigating specific barriers and enablers with in these dimensions, for example through qualitative research capturing lived experiences of individuals and communities, would be valuable. To complement, longitudinal studies could shed light on how perceptions and attitudes toward smart city technologies in the Global South evolve over time.

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Economic Investigation into Rainwater Harvesting and Greywater Reuse in Decentralized Residential Units: A Case Study from Bursa

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ABSTRACT

Unplanned urbanization, climate change, scarcity, and pressure on water resources necessitate sustainable urban water management practices to ensure water security. In this study, a sustainable solution for addressing the increasing urban water demand was presented, focusing on the recycling potential of greywater and rainwater for a residential site. The project included an evaluation of the economic dimensions of the components (piping, treatment, storage, etc.). Greywater includes domestic wastewater originating from sinks, showers, baths, and washing machines. Rainwater is collected from roofs, stored, and can be used in various areas, such as irrigation and cleaning. In the study, the amount of greywater and rainwater that can be recycled from a sample site consisting of 6 blocks and 96 apartments was evaluated with system design and economic feasibility. Daily greywater production in the project area was calculated as approximately 55,296 liters. Rainwater collected from roofs can be used in landscape irrigation, thus reducing drinking water consumption and wastewater volume. The study presented an economically applicable and environmentally compatible solution proposal for cities that are compatible and resilient to climate change.

Keywords: Greywater, rainwater, recycling, eco-efficient infrastructure, adaptation to climate change

Introduction

With the growing population and urbanization, the demand for clean water resources is increasing. Therefore, the recovery of alternative water resources is crucial for sustainable water management [1]. Greywater and rainwater recovery systems, especially for decentralized settlements, offer cost-effective and environmentally friendly solutions to the increasing water demand [2-4]. Greywater and rainwater, a portion of residential wastewater, hold significant potential for reuse. Greywater is low-organic household wastewater from showers, sinks, and washing machines. When treated properly, this water can be reused for purposes like garden watering, feeding toilet tanks, and cleaning. Rainwater can be collected from rooftops and made usable through simple filtration and storage systems. Using these resources together helps reduce water use and promotes environmental sustainability [3-5].
In this context, Bursa province, while influenced by the Mediterranean climate, faces the risk of drought due to rising temperatures and decreasing precipitation due to climate change [6]. As a result of increasing population and industrialization, water demand is constantly increasing, and existing infrastructure is insufficient to meet this demand [7]. Infrastructure modernization and water recycling practices carried out by water and sewerage administrations are gaining importance as a solution to this situation. The aim is to strengthen water

management through leakage detection, rainwater separation systems, and distribution line improvements [8,9]. Recent studies show that such local recycling systems are economically feasible in urban areas and increase cities' capacity to adapt to climate change [10,11]. All data demonstrate that climate adaptation, alternative resource use, and infrastructure investments must be addressed together for a sustainable water supply in Bursa [12]. Recent studies suggest that integrating graywater and rainwater systems, particularly in urban areas, is both feasible and economical. Implementing these systems at the building or site scale reduces dependence on centralized systems and strengthens cities' capacity to adapt to climate change and their approach to urban water sustainability [13].
This study aims to evaluate the technical and economic aspects of graywater and rainwater recovery in a residential area in Bursa province, which could contribute to sustainable urban water management and eco-efficient infrastructure systems.

Methodology

The residential area covered in this study comprises a total of 96 apartments. The area includes six blocks of four stories, each with four apartments per floor, giving a total of 16 apartments per block. Assuming each apartment is approximately 100 m² in size and has an average population of four people, a total residential area of 384 people is envisaged (Figure 1).

Literature indicates that graywater production per capita in multi-story residential buildings ranges from 90 to 150 liters per day [14]. This study, based on a similar feasibility study conducted by Gürbüz and Öztürk (2021) [15], used a value of 144 L/day per capita, resulting in a projected graywater production of approximately 55,296 L/day. Only wastewater from showers, sinks, and washing machines was considered as graywater sources; toilet and kitchen water were excluded. This choice reduces the organic load of the system and increases treatment efficiency [14].

Greywater collected in residential units via a separate piping system is directed to a central treatment unit. The Membrane Bioreactor (MBR) system was chosen for the treatment process due to its high treatment efficiency, compact structure, and suitability for the settlement scale. MBR systems are widely used, especially in decentralized areas, because they provide higher dissolved substance removal compared to conventional activated sludge systems [15]. A study conducted in Alanya also emphasized the advantages of MBR systems in terms of cost and space [14].

Greywater treated with the MBR system is recycled through a disinfection unit and then reused in toilet cisterns. Membrane surface area and tank volumes were determined in the system design, considering the number of users, daily flow rate, and loading parameters.

Rainwater management was also evaluated within the scope of the study. Considering the total roof area of the six blocks and the long-term average rainfall in Bursa province, an annual rainwater potential of approximately 1,875 m³ was calculated. After pretreatment, rainwater is planned to be used in landscaped areas through a drip irrigation system. In the Alanya sample, this approach was reported to contribute to water savings [14].

The layout plans, piping arrangement, and equipment layouts for both systems were modeled in AutoCAD. Pipe diameters, flow rates, hydraulic gradients, and tank volumes were designed based on the TS EN 16941-1 standard and application examples in the literature. The methodology used in a similar study conducted in Istanbul was used to determine investment costs, and pricing was based on bids received from local suppliers. Cost items included piping, MBR unit, disinfection system, pumps, and storage units [15].

Main Results and Discussion

In the residential area, water consumption patterns were calculated based on literature data, and a daily per capita greywater production of 144 L per person and a total greywater potential of 55,296 L/day were calculated [14-16]. This amount is considered significant not only for its potential for reuse for non-drinking purposes but also for its potential to reduce the load on wastewater treatment systems [2]. This potential represents a significant resource for the recovery of alternative water sources. Furthermore, based on the average annual rainfall on the block roofs, approximately 1875 m^3/year of rainwater was calculated for the entire site. Plans were made to use this water, particularly for the irrigation of landscaped areas.

The study focused on calculating greywater and rainwater infrastructure lines, directing greywater to a central treatment unit, and collecting and storing rainwater. The layout plan shown in Figure 1 demonstrates a holistic integration of this system across the blocks. Membrane bioreactor (MBR) technology was planned for graywater treatment. Treated water was reused in the system for use in toilet cisterns after filtration and disinfection processes, while rainwater was integrated with drip irrigation systems after mechanical filtration and utilized for irrigation of green spaces [17]. This study evaluated the equipment and labor requirements for graywater and rainwater infrastructure systems to be implemented in a residential area consisting of 96 apartments. Table 1 lists the equipment and cost-generating components to be used for the graywater and rainwater recovery line. The data in Table 1 includes the lateral and vertical pipes used for the collection and transportation of raw graywater, the system for treating the collected graywater, tanks, and pumps [6]. Data regarding the pipes, connection equipment, and equipment to be used for rainwater collection and storage are also presented in the table. The design of both systems was made by considering material selection and application requirements; all hydraulic calculations and cost analyses were conducted after detailed market research [11-18]. The cross-section shown in Figure 2 shows the lateral and vertical piping details of the greywater and rainwater systems of a block. The transmission of greywater from the floors to the central treatment system and the transfer of rainwater filtered from the roof to the storage tank are schematically presented. This cross-section reflects the layout of the system within the building. The systems were planned with a holistic approach to contribute to sustainable water management. This system significantly reduces mains water consumption, prevents direct discharge of wastewater into the sewer system, and reduces environmental impacts. It has been calculated that water savings of up to 56% can be achieved in implemented applications, demonstrating both the ecological and economic efficiency of the system. Similar studies in Türkiye also indicate that the highest environmental contribution of such systems comes from water and energy savings, with a 40–60% lower environmental impact compared to central infrastructure [19-20].

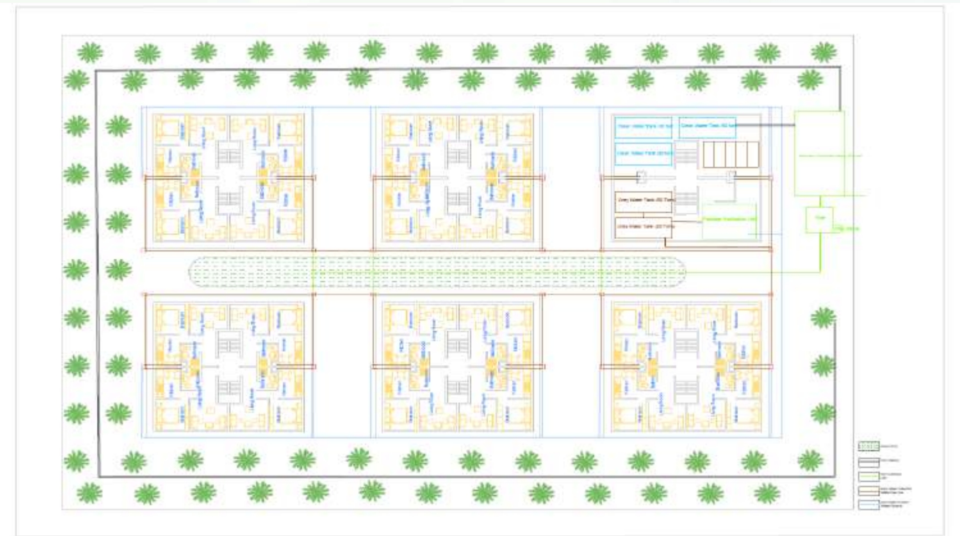

Figure 1. Greywater and Rainwater Recycling Systems in the Residential Area

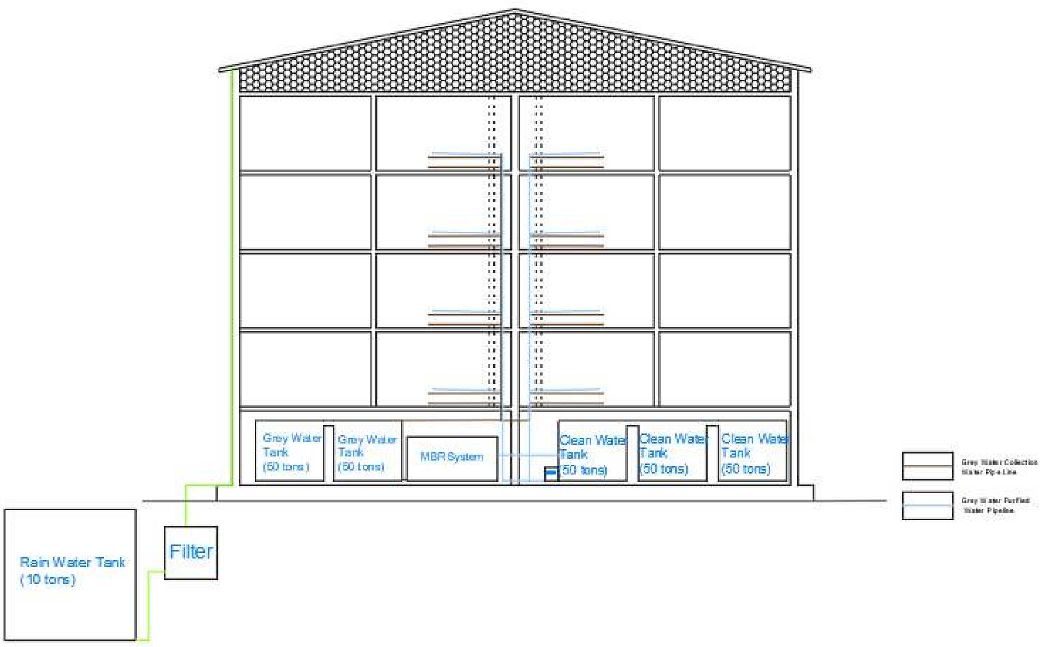

Figure 2. Vertical and lateral sections for a block and rainwater collection and greywater recycling systems

Table 1. Greywater and Rainwater System Costs

Component	Costs (₺)
Greywater	
Piping	379.000
Labor	615.000
Equipment (Tank, Pump)	805.000
Treatment (MBR)	900.000
Additional Expenses	36.000
Total	**2.735.000**
Rainwater	
Piping	151.500
Labor	120.000
Equipment (Tank, Pump, Filter)	125.000
Additional Expenses	18.500
Total	**415.000**

Investment costs vary depending on system size, and as the system grows, the cost per apartment decreases and the payback period decreases. Literature indicates that installing the system in buildings with 15-20 apartments requires a cost of approximately €600 per apartment, while costs drop to as low as €200 for complexes with more than 500 apartments [8]. Considering the current Euro exchange rate (46 ₺), an approximate cost of €625 per apartment was calculated for the project, and this value is consistent with literature data [21]. The payback period for the system was calculated as 6.3 years, based on the net annual income determined by BUSKİ (Bursa Water and Sewerage Administration) as 25 ₺ per m^3 of water. This investment pays for itself in approximately six years. This value is within acceptable limits for water recycling systems in decentralized settlements and supports its applicability for medium-sized complexes [3]. The system's performance throughout the year may fluctuate due to user habits and seasonal water usage changes. In summer, increasing shower frequency and green area irrigation increases the amount of greywater and rainwater recycling; however, water amounts may decrease in winter [22]. It has been stated that system selection based on the water source and intended use is critical in determining appropriate treatment methods for greywater reuse [23]. Furthermore, correct and continuous use of the systems by users is also a determining factor in efficiency [24]. When the annual savings were calculated, 22,052 m^3 of mains water was used, and similar systems are reported in the literature to save 10,000–30,000 m^3 of water annually; in this context, the results of the study present a very positive picture from an environmental perspective, considering the system scale and user density [25].

Conclusion

In this study, greywater and rainwater management in a 96-unit residential complex in Bursa was evaluated in terms of sustainability and economic efficiency. Calculations revealed a potential to collect 55,296 liters of greywater and 1875 m^3 of rainwater from annual rainfall. The MBR system was chosen for greywater treatment due to its low energy requirements and high purification performance. This system achieved 56% water savings. The collected rainwater supported the natural water cycle and, by reducing surface runoff, contributed to minimizing flood risk and water conservation. The integration of greywater treatment and rainwater harvesting at different scales enables the efficient use of alternative water sources in urban infrastructure systems. The implemented systems alleviate the water supply burden by reducing mains water consumption and minimizing environmental burdens by reducing wastewater discharge. Application results reveal that system efficiency varies depending on site conditions, climatic conditions, and user habits. Considering the system's savings and payback period of 6.3 years, the system is considered efficient. To expand such applications in Turkey, low-energy, modular systems should be encouraged, and technical standards and regulations should be developed. Practices such as rainwater harvesting and graywater recycling, which contribute to urban sustainability, offer environmental solutions for adapting to climate change by reducing pressure on water supply and treatment infrastructure. Effectively utilizing this potential can reduce the demand pressure on existing centralized water supply systems. This contributes to increasing water supply security, especially during dry periods, and preventing the overexploitation of groundwater resources.

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An Insight into the Kahramanmaraş Public Transportation System Using Statistical and Artificial Intelligence Methods

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ABSTRACT

This study investigates the transition of Kahramanmaraş's public transportation system from a fragmented minibus based model to a centralized municipal bus network, emphasizing its impact on passenger satisfaction. A structured 13-item Likert-scale survey was conducted with 85 participants at key transit hubs, and the results were analyzed using both SPSS and Artificial Neural Networks (ANN). Statistical analysis revealed improvements in service frequency and comfort, while concerns remained regarding access to travel information and complaint handling. The ANN model was developed to assess the relative importance of socio-demographic and behavioral variables in shaping satisfaction. Permutation-based feature importance analysis indicated that gender, particularly female respondents, was the most influential factor, followed by private vehicle ownership and educational background. These findings reveal pronounced differences in service perception across user groups. Notably, young passengers, especially university students, played a crucial role in shaping feedback due to their high share among public transport users. The study demonstrates the value of AI-based tools for identifying complex patterns in survey data and informing user-centered transit planning. By integrating statistical and machine learning approaches, this research offers practical insights for designing more inclusive and sustainable urban mobility strategies, not only in Kahramanmaraş but also in similar mid-sized metropolitan areas.

Keywords: Kahramanmaraş, Public Transportation, SPSS, ANN, Survey Analysis

Introduction

Kahramanmaraş is a metropolitan city in southern Türkiye with a population of approximately 1.2 million. The urban center comprises the districts of Dulkadiroğlu and Onikişubat. The city's public transportation system operates a fleet of around 510 buses across 10 main routes, supported by the Kahramankart smart fare system. The system in the city was, historically, fragmented among municipal buses, private public buses, and minibuses. This lack of coordination resulted in overlapping routes, underutilized vehicle capacity, and overall inefficiency.

To address these issues, a major transformation was initiated in 2015, by phasing out minibus fleets and consolidating services into a unified public bus network. To evaluate the outcomes of this transformation, a structured survey was conducted in 2023 with 85 participants. The survey included 13 Likert-scale questions grouped under four categories: usability, system information, customer satisfaction, and comfort.

Passenger satisfaction in public transport is often influenced by key service quality factors such as accessibility, punctuality, cleanliness, and seat availability (1,2). While traditional statistical approaches have long been used for analysis, recent advances in artificial intelligence (AI) particularly neural networks and deep learning methods have significantly improved prediction accuracy and interpretability in transport-related studies(3,4). These methods improve satisfaction analysis and support demographic profiling, helping to create more inclusive and responsive transportation plans(5).
This study applies AI-based models to survey data from Kahramanmaraş to identify key factors shaping public transportation satisfaction and explore the utility of AI in evaluating and improving urban mobility systems.

Methodology

The field study was conducted at three key public transportation nodes in Kahramanmaraş: Ulucami, Museum, and City Centre bus stops. These locations were selected due to their high passenger density and centrality within the urban bus network.

Figure 1. A map showing the three survey locations marked within the Kahramanmaraş city enter.

A total of 85 participants were surveyed at these locations. Each participant answered 13 questions rated on a 6-point Likert scale (1 = strongly dissatisfied, 6 = strongly satisfied), with 7th indicating no opinion. The survey questions were grouped into four thematic categories as shown below:

Table 1. Survey question groupings under four categories–System Information, Customer Satisfaction, Usability, and Comfort.

Main Criteria	Features	Questions
System Information	Frequency, Waiting Time, Crowding, Travel Time, Route Coverage, And Departure Times	Q1–Q5, Q13
Customer Satisfaction	Access to Travel Info and Complaint Handling	Q6–Q7

Usability	Staff Behaviours and Ticket Pricing	Q8–Q9
Comfort	Seating, Cleanliness, And Environment	Q10–Q12

To complement the statistical analyses performed via SPSS, a supervised machine learning approach was implemented using an artificial neural network constructed in Python with the Keras API. The model aimed to predict individual responses to 13 Likert-scale survey items based on socio-demographic and behavioral variables.

The architecture consisted of a feedforward neural network with two fully connected hidden layers containing 128 and 64 neurons, respectively. ReLU (Rectified Linear Unit) was used as the activation function for the hidden layers, while the output layer employed a linear activation function to handle the continuous nature of the target variables. The model was trained using the Adam optimization algorithm and the Mean Squared Error (MSE) loss function, with input features standardized prior to training. Model performance was evaluated on a held-out test set using the Mean Absolute Error (MAE) metric.

Permutation feature importance was applied to interpret the influence of each input variable on the predictions. In this method, each input feature was randomly permuted across test samples, and the resulting change in MSE was calculated. The features that produced the largest increase in error were interpreted as the most influential. This interpretability analysis provided insights into the relative importance of variables such as gender, marital status, educational attainment, employment status, and vehicle ownership in shaping participants' survey responses.

Main Results and Discussion

The analysis of survey data provides important insights into how passengers perceive various dimensions of the restructured public transportation system in Kahramanmaraş. While the overall sentiment reflects moderate satisfaction, specific areas emerge as either strengths or points of concern. These findings help identify which operational and experiential elements of the system resonate well with users and which require further improvements.

As shown in Table 2, frequency of service (Q1) stands out with the highest satisfaction score (M = 4.54), suggesting that regularity of buses is well aligned with passenger expectations. In contrast, travel information (Q6) received the lowest score (M = 2.01), indicating a persistent gap in the clarity or availability of route and schedule data. Perceptions related to crowding (Q4) and driver behaviour (Q8) showed notable gender-based differences, where female respondents reported lower satisfaction. The high standard deviation in complaint mechanisms (Q7) points to inconsistent user experiences. Collectively, these results emphasize the need for the attention of delivering improved information to gender-sensitive service design.

Table 2. Summary Statistics of Key Survey Questions

Question	Topic	Mean	Std. Dev.	Results
Q1	Frequency (Usability)	4.54	1.41	Highest rated question
Q4	Crowding (Usability)	3.36	1.33	Gender difference observed
Q7	Complaints (Info)	3.01	1.91	High variance in responses
Q8	Driver (Satisfaction)	3.56	1.51	Male-female perception gap
Q6	Travel Info (Info)	2.01	1.61	Lowest satisfaction reported

The influence of socio-demographic characteristics on passenger satisfaction was further examined through permutation-based feature importance analysis using the trained artificial neural network (ANN) model, as illustrated in Figure 2.

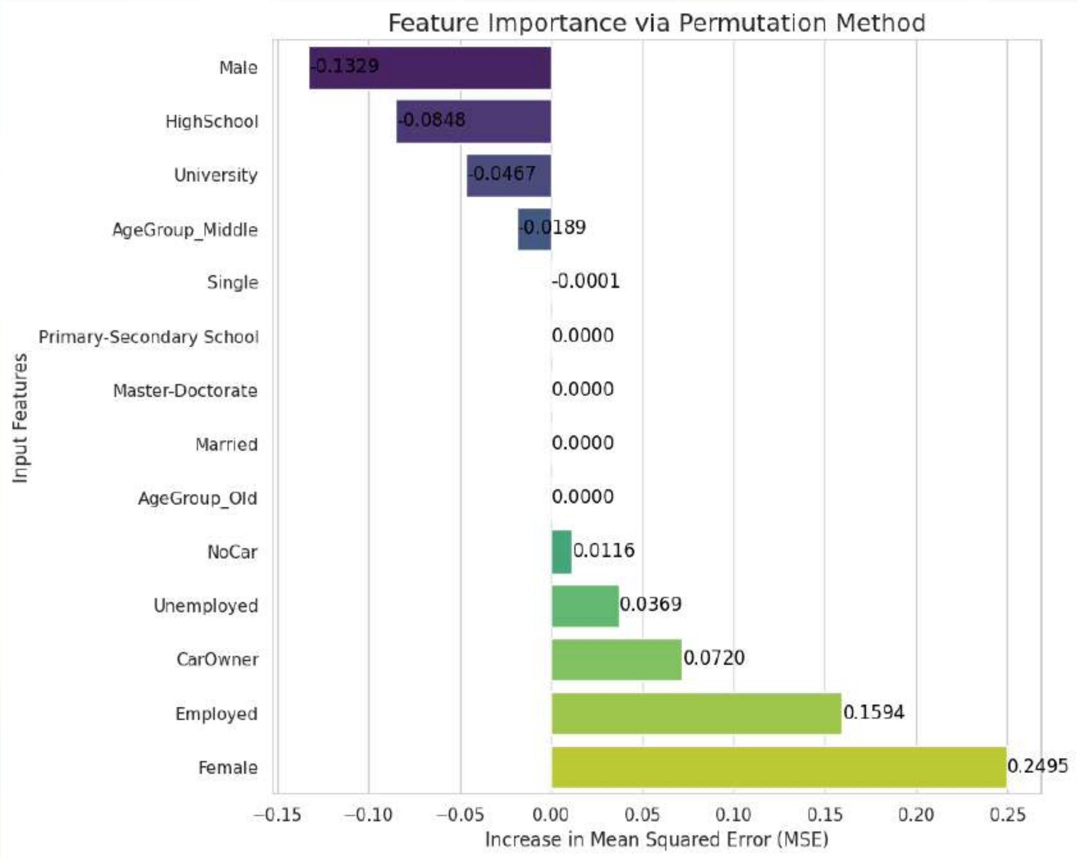

Figure 2. Feature Importance Rankings Based on Permutation Analysis from the ANN Model

The trained ANN model achieved a Mean Absolute Error (MAE) of 1.075 on the test dataset. This indicates that predicted satisfaction scores deviated, on average, by approximately one point from the actual survey ratings, confirming that the ANN model provided satisfactory predictive accuracy in capturing the relationship between socio-demographic variables and passenger satisfaction.

In this study, descriptive statistics and an artificial neural network (ANN) were used to analyse the data. The goal was to find out which socio-demographic factors had the highest effects. The ANN model enabled a detailed assessment of which input variables had the greatest impact on survey responses. Among all predictors, gender specifically the "Female" category emerged as the most influential feature, indicating notable differences in satisfaction levels between male and female respondents. Private vehicle ownership ("CarOwner") was the second most impactful factor, suggesting that those who own personal cars exhibit distinct perceptions compared to those without access to private transportation. Other demographic variables, such as education level, marital status, and employment, also contributed to variations in satisfaction, though to a lesser extent.

The findings indicate that service frequency is the strongest aspect of Kahramanmaraş's restructured public transport system, with the highest satisfaction score (M = 4.54), showing that bus schedules meet passenger expectations and provide reliability, especially for students and workersIn contrast, travel information received the lowest rating (M = 2.01), which may reflect that many passengers have not yet developed the habit of using public transport applications to check bus schedules and locations, suggesting that this practice will likely improve gradually over time. Gender-based differences were evident, as women reported lower satisfaction with crowding and driver behaviour, highlighting the need for gender-sensitive service design. The high variability in ratings for complaint mechanisms suggests inconsistent performance across different areas and situations. ANN analysis confirmed gender as the most influential factor on satisfaction, followed by private vehicle ownership, with education, marital status, and employment playing smaller roles. The majority of respondents were young people, particularly university students, pointing to the importance of integrating digital tools such as mobile applications, real-time tracking, and electronic information boards to improve user experience and meet the expectations of this tech-oriented demographic.

A total of 85 participants surveyed, of whom 62% aged 25 or below and 47% aged 22 or below were university students. This clearly demonstrates that the research was strongly supported by young people, who represent the majority of public transportation users in the city. Their input was not only essential in identifying the current problems within the system but also served as the foundation for shaping the proposed transportation model. Rather than being passive respondents, these young participants actively contributed to the evaluation process, making their voices a central element in the redesign of the system. This approach helps shape future urban transportation around the needs and expectations of younger users.

Conclusion

This study assessed passenger satisfaction with the reformed public transportation system in Kahramanmaraş through a structured survey and analysed the influence of socio-demographic factors using an artificial neural network (ANN) model. The findings indicate an increase in overall satisfaction compared to the previous system, largely attributed to improvements such as vehicle renewal, increased capacity, and better maintenance standards. However, challenges like resistance to change, adaptation to new technologies, and the impact of economic conditions remain. Feature importance analysis based solely on the ANN model revealed that education level, gender, employment and marital status play significant role in the evaluation of the services by the passengers. These findings indicate that AI-based methods are useful tool to understand the evaluations and thoughts of different users on the service provided. This can help create more user focused and data-driven public transport policies. For sustainable impact, such transformations should be embedded within a broader urban mobility framework promoting integration with alternative transport modes and long-term planning.

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Evaluation of the YeS-TR Settlement Certification System within the Scope of Sustainable Development Goals

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ABSTRACT

This study evaluates the direct relationship between Turkey's national green settlement certification system, the Green Certificate Settlement (YeS-TR Settlement), and the United Nations Sustainable Development Goals (UN SDGs), as well as its contribution to these goals. YeS-TR Settlement criteria were comparatively analyzed in relation to the SDGs. The study aims to demonstrate that YeS-TR Settlement is an effective tool for promoting sustainable and resilient urban development, to assess its alignment with global goals, and to encourage its broader implementation. Its significance lies in YeS-TR Settlement being a context-specific, cost-effective, and accessible system tailored to Turkey's national conditions, offering strategic potential to advance the country's sustainability agenda. The analysis utilized the most recent version of the Green Certificate Settlement Evaluation Guide issued by the Ministry of Environment, Urbanization, and Climate Change of the Republic of Turkey, along with official UN SDG documentation. A qualitative content analysis method was employed, and findings derived through conceptual matching were presented in tables. The study's scope was determined by the objectives, content, and requirements of both the certification system and the global goals. Only direct linkages between criteria and goals were considered, excluding indirect or potential associations. According to the findings, the goals with the highest number of direct linkages are "SDG 11: Sustainable Cities and Communities," "SDG 13: Climate Action," and "SDG 3: Good Health and Well-being." Goals with the fewest associations include "SDG 5: Gender Equality," "SDG 4: Quality Education," and "SDG 14: Life Below Water." Overall, the YeS-TR Settlement certification system incorporates criteria aligned with environmental, social, and economic sustainability, contributing meaningfully to global sustainability efforts. These results are intended to inform future research on the integration of national certification systems into global sustainability frameworks and to foster awareness of sustainable settlements in Turkey.

Keywords: Sustainable Development Goals (SDGs), YeS-TR Settlement, National Green Certification Settlement, Urban sustainability, Green settlements

Introduction

The concept of sustainable development, encompassing economic, environmental, and social dimensions, was first defined in the report titled Our Common Future, also known as the Brundtland Report, in 1987. According to this definition, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. Economic sustainability aims at the efficient use of resources and the promotion of economic development. Issues such as reducing environmental impacts and using natural resources efficiently are evaluated within the scope of environmental sustainability. Ensuring social equity and increasing societal well-being fall under the scope of social sustainability [2].

Today, with increasing population and urbanization, environmental problems are intensifying, threatening natural resources. In this context, the concept of sustainable urbanization has gained importance as a holistic approach aiming to reduce environmental impacts, increase economic efficiency, and support social welfare [3, 4]. Sustainable cities aim to offer a livable environment for both current and future generations through energy-efficient buildings, integrated transportation systems, public green spaces, and environmentally friendly infrastructure. Green building and settlement certification systems developed in line with this objective are important tools for evaluating and improving the sustainability performance of cities. Through these systems, urban areas are designed and managed in a more sustainable manner based on criteria such as energy use, water efficiency, material selection, healthy living conditions, and ecological compatibility [5, 6]. Therefore, there is a strong and strategic relationship between green certification systems and sustainable urbanization goals.

The Sustainable Development Goals declared by the United Nations in 2015 consist of 17 global goals to be achieved by 2030, encompassing multidimensional objectives such as combating poverty, reducing inequalities, protecting the environment, and increasing global well-being [7]. The global goals emphasize that development cannot be reduced to economic growth alone and that areas such as environmental sustainability and social inclusion must also be addressed in an integrated manner [8]. These goals lead to the development of sustainable policies and practices, particularly in areas such as urbanization, infrastructure, climate change, and resource management.

Turkey's national green building and settlement certification system, YeS-TR (Green Certificate-Türkiye), was developed under the coordination of the Ministry of Environment, Urbanization, and Climate Change of the Republic of Turkey, with technical support primarily from Istanbul Technical University and other academic institutions. This system is an assessment framework applicable at the building and settlement scale, designed in accordance with local conditions [9, 10]. Unlike international systems, YeS-TR considers climatic, cultural, and geographical particularities and offers an adaptable structure for local governments and practitioners. In this sense, the significance of the YeS-TR Settlement lies in its being a system developed to suit Turkey's specific conditions—accessible, applicable, and more sustainable in terms of cost. YeS-TR Settlement aims to guide the planning, design, and implementation processes of urban settlement areas in line with sustainable urbanization principles. The system consists of six main modules: Regional and Immediate Environment Profile (BOL), Sustainable Land Use, Ecology and Disaster Management (AKE), Transportation and Mobility (UHA), Urban Design (KET), Social and Economic Sustainability (SES), and Innovation in Settlement (INO). Through these modules, sustainability, disaster resilience, climate adaptation, social equity, and user comfort are evaluated in a comprehensive manner [11]. The YeS-TR Settlement Certificate is positioned as a strategic tool to support sustainable urban policies at the national level.

In the current literature, there is no study found that specifically addresses the relationship between the YeS-TR Settlement certification system and the United Nations Sustainable Development Goals. This not only highlights the originality of this study but also underlines the gap it aims to fill in the literature. However, there are studies examining the relationship between other green building/settlement certification systems and the Sustainable Development Goals. In this regard, it can be stated that the LEED (Leadership in Energy and Environmental Design) certification system stands out in particular.

This study aims to conceptually evaluate the alignment between the YeS-TR Settlement certification criteria and the Sustainable Development Goals. The main objective of the study is to understand this relationship and emphasize the importance of YeS-TR Settlement in building resilient and sustainable cities. Raising awareness on this issue and supporting the dissemination of the system are among the secondary objectives. The Green Certificate Settlement Evaluation Guide and the United Nations Sustainable Development Goals were used as data sources in the study. The methodology of the study is based on qualitative content analysis. The information obtained through conceptual matching was visualized using tables. The objectives, scope, and requirements of the criteria and goals define the boundaries of the study. Only direct relationships were taken into account in the analyses, and indirect and potential relationships were excluded from the study. Understanding this relationship will contribute to the development of sustainability practices that are more globally aligned in urban planning.

In the introduction section, which forms the first part of the study, the conceptual framework is briefly explained, and the purpose, scope, method, and significance of the study are addressed. This is followed by the materials and methods section. In the findings section, which presents the analysis results of the study, each module is analyzed in detail, and the analysis results are presented in tables. The results obtained in the findings section are discussed in the discussion section and evaluated in general terms in the conclusion section.

Methodology

Within the scope of the study, all six modules and criteria of the YeS-TR Settlement certification system were associated with the Sustainable Development Goals (SDGs) based on various grounds. The most recent YeS-TR Settlement Evaluation Guide and the official documents of the 2030 Agenda for Sustainable Development published by the United Nations were used as the main materials in the study. A qualitative content analysis method was adopted, and the document review (documentary analysis) technique was applied. Conceptual relationships were established between the criteria and the goals, and each criterion was associated with one or more global goals (conceptual matching). Only direct relationships were considered in the study, while indirect and potential relationships were disregarded. These direct relationships established between the global goals and the certification criteria are presented through tables (frequency analysis). From these tables, the global goal(s) associated with each module and/or those with the highest frequency of association can be identified. In this way, qualitative data have been systematized and comparability has been facilitated. Furthermore, reproducibility and scientific transparency have been ensured. The coding was carried out manually by the researcher. The research process is summarized in Figure 1.

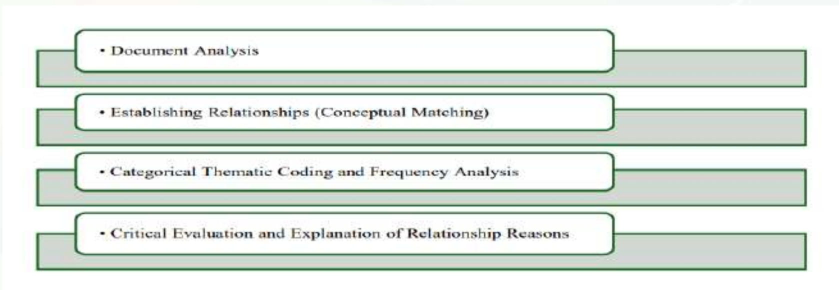

Figure 1. Research process and method diagram.

This study was conducted in accordance with the principles of scientific research and publication ethics.

While establishing conceptual matching, the official definitions of the criteria and the goals were taken as the basis, and subjective judgments were avoided. Through this study, the YeS-TR Settlement certification system was evaluated in terms of the Sustainable Development Goals; the aim was to contribute to the literature, to promote Turkey's national green settlement certification system, and to raise awareness about this system.

Findings

In this section, all criteria of the YeS-TR Settlement certification system are associated with the United Nations Sustainable Development Goals (SDGs) based on their direct relationships. Only direct relationships between the criteria and the goals were addressed, while potential and indirect relationships were disregarded. The direct relationships identified between all YeS-TR Settlement modules and criteria and the global goals are presented in this section in the form of tables. Through these tables, it is possible to determine which module is more or less associated with which goal, as well as to identify the specific goals directly linked to the criteria within any given module.

- ***Regional and Immediate Environment Profile (BOL)***

This theme aims to support the sustainable development of small and medium-sized cities by fulfilling the requirements at administrative, legal, and planning levels. Other objectives include defining the size of the designated area, ensuring participation and communication with project stakeholders, and managing the implementation and financial processes. In this way, settlement areas applying for certification can meet the basic conditions in terms of planning principles, urban development guidelines, and public interest [11]. The criteria under this theme are directly associated with eight different SDGs (1, 9, 10, 11, 13, 15, 16, 17). The relationships established between this theme, its criteria, and the relevant goals are presented in Table 1.

Table 1. Global goals directly related to the criteria of the YeS-TR Settlement BOL module

Theme	Criteria	P / O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BOL 01	C1	P											✓		✓		✓		
	C2	P	✓									✓	✓						
	C3	P									✓		✓					✓	
BOL 02	C1	O									✓		✓		✓			✓	✓
	C2	O										✓	✓					✓	✓

The goal most directly associated with this theme is "SDG 11: Sustainable Cities and Communities." Although there are global goals with no established direct relationship, the goals least directly linked are "SDG 1: No Poverty" and "SDG 15: Life on Land."

- ***Sustainable Land Use, Ecology, and Disaster Management (AKE)***

The primary objective of this theme is the protection of the natural environment and the assurance of sustainable land use and disaster management. Appropriate site selection decisions are crucial from various perspectives. Examples include the conservation of ecological values, implementation of energy-efficient approaches, proper utilization of natural and physical features, and adoption of suitable settlement and transportation decisions. Additionally, ensuring cross-scale integration for both existing and new urban settlements, enhancing public interaction, conducting studies on urban disaster management, and making environmentally focused, holistic decisions in urban infrastructure are among the general objectives [11]. The criteria under this theme are directly associated with eleven different SDGs (3, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16). The relationships established between this theme, its criteria, and the relevant goals are presented in Table 2.

Table 2. Global goals directly related to the criteria of the YeS-TR Settlement AKE module

Theme	Criteria	P / O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
AKE 01	C1	P											✓				✓	✓	
	C2	O											✓				✓		
	C3	O											✓		✓	✓	✓		
AKE 02	C1	P							✓						✓				
	C2	O							✓		✓		✓		✓				
	C3	O							✓						✓				
	C4	O							✓				✓		✓				
AKE 03	C1	O									✓	✓	✓	✓	✓		✓		
	C2	O			✓								✓						
AKE 04	C1	O			✓							✓	✓		✓				
	C2	O			✓							✓	✓		✓				
AKE 05	C1	O						✓					✓	✓	✓				
	C2	O						✓			✓		✓	✓	✓				
	C3	O			✓								✓	✓					

The goal most directly associated with this theme is "SDG 11: Sustainable Cities and Communities." While there are global goals with no established direct relationships, the goals least directly linked are "SDG 14: Life Below Water" and "SDG 16: Peace, Justice, and Strong Institutions."

- ***Transportation and Mobility (UHA)***

This theme primarily aims to support pedestrian-priority transportation and ensure traffic safety, while also guiding urban planning and design decisions based on livability factors. The improvement of existing transportation networks and the reduction of vehicle dependency are also considered within this scope [11]. The criteria under this theme are directly associated with ten different SDGs (3, 6, 7, 8, 9, 10, 11, 12, 13, 15). The relationships established between this theme, its criteria, and the relevant goals are presented in Table 3.

Table 3. Global goals directly related to the criteria of the YeS-TR Settlement UHA module

Theme	Criteria	P / O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
UHA 01	C1	P											✓						
	C2	P											✓		✓				
	C3	O											✓		✓				
	C4	O			✓								✓		✓				
	C5	O									✓		✓						
	C6	O			✓								✓						
	C7	O								✓			✓		✓				
UHA 02	C1	P											✓		✓				
	C2	O			✓								✓		✓				
	C3	O			✓								✓		✓				
	C4	O			✓								✓		✓				
UHA 03	C1	P										✓	✓		✓				
	C2	O			✓							✓	✓						

	C3	O											✓		✓				
	C4	O			✓								✓		✓				
UHA 04	C1	O									✓		✓		✓				
	C2	O											✓		✓		✓		
	C3	O											✓		✓				
	C4	O						✓					✓		✓				
	C5	O							✓				✓		✓				
	C6	O											✓	✓	✓				

The goal most directly associated with this theme is "SDG 11: Sustainable Cities and Communities." Although there are global goals with no established relationship, there are multiple goals (6, 7, 8, 12, and 15) with which the least direct relationships were identified.

- ***Urban Design (KET)***

This theme aims to design sustainable, green, and healthy cities/areas. It encourages sustainable and flexible projects that preserve local identity and reflect the region's unique characteristics. As it particularly emphasizes ensuring the accessibility of public spaces, it is generally considered a module that supports active living [11]. The criteria under this theme are directly associated with twelve different SDGs (1, 2, 3, 7, 8, 9, 10, 11, 12, 13, 15, 16). The relationships established between the theme, its criteria, and the relevant goals are presented in Table 4.

Table 4. Global goals directly related to the criteria of the YeS-TR Settlement KET module

Theme	Criteria	P / O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
KET 01	C1	O										✓	✓		✓			✓	
	C2	O								✓			✓	✓					
	C3	O											✓						
KET 02	C1	O			✓							✓	✓		✓				
	C2	O			✓								✓		✓				
	C3	O			✓						✓		✓		✓				
KET 03	C1	O			✓							✓	✓					✓	
	C2	O			✓								✓		✓				
	C3	O		✓	✓					✓			✓	✓	✓				
KET 04	C1	O			✓					✓			✓		✓				
	C2	O										✓	✓						
KET 05	C1	O											✓	✓	✓		✓		
	C2	P							✓				✓	✓	✓				
	C3	O	✓									✓	✓						
KET 06	C1	O											✓		✓				
	C2	O											✓		✓		✓		
	C3	O											✓		✓				
	C4	O			✓								✓						
	C5	O			✓				✓					✓	✓		✓		
	C6	O									✓			✓	✓				

The goal most directly associated with this theme is "SDG 11: Sustainable Cities and Communities." Although there are global goals with no established relationship, the goals least directly associated are "SDG 1: No Poverty" and "SDG 2: Zero Hunger."

- ***Social and Economic Sustainability (SES)***

It aims to improve the quality of life in settlements by ensuring social and economic sustainability. Its objectives include improving economic welfare levels, promoting sustainable production and consumption, strengthening social equity and inclusiveness, maintaining life-supporting urban systems, and preserving the natural and cultural environment. Additionally, it aims to contribute to the establishment of healthy, safe, inclusive, fair, and innovative social and economic structures. It supports an economic structure that offers high quality of life, ample employment opportunities, competitiveness, and eco-efficiency [11]. The criteria of this theme have been directly associated with ten different SDGs (1, 2, 3, 4, 8, 9, 10, 11, 12, and 16). The relationships established between the theme, its criteria, and the relevant goals are presented in Table 5.

Table 5. Global goals directly related to the criteria of the YeS-TR Settlement SES module

Theme	Criteria	P / O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SES 01	C1	O										✓	✓					✓	
	C2	O										✓	✓						
	C3	O				✓				✓									
	C4	O	✓									✓	✓					✓	
	C5	O								✓	✓								
	C6	O								✓									
	C7	O								✓									
	C8	O								✓	✓	✓							
SES 02	C1	O			✓								✓						
	C2	O			✓							✓	✓						
	C3	O		✓									✓	✓					

The goal most directly associated with this theme is "SDG 11: Sustainable Cities and Communities." Although some global goals have no established direct relationship, several goals (1, 2, 4, and 12) exhibit the least direct association.

- ***Innovation Settlement (INO)***

It promotes the use of information and communication technologies to enhance the quality of life and sustainability of settlements, encouraging continuously monitorable and innovative planning. Unlike the criteria defined in other modules, it focuses on improving individual and societal quality of life through innovative solutions. It aims to ensure the participation of individuals in service management, support a conscious consumer profile through efficient use of resources, and promote all improving and innovative policies [11]. The criteria of this theme have been directly associated with nine different SDGs (3, 6, 7, 9, 11, 12, 13, 16, and 17). The relationships established between the theme, criteria, and goals are presented in Table 6.

Table 6. Global goals directly related to the criteria of the YeS-TR Settlement INO module

Theme	Criteria	P / O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
INO 01	C1	O									✓		✓		✓				✓
	C2	O			✓						✓		✓					✓	✓
INO 02	C1	O						✓	✓		✓		✓	✓	✓				

The goals most directly associated with this theme are "SDG 9: Industry, Innovation, and Infrastructure" and "SDG 11: Sustainable Cities and Communities." Although some global goals have no established direct relationship, there are multiple goals with the least direct association (3, 6, 7, 12, and 16).

Discussion

According to the results of the documentary analysis and conceptual matching, the YeS-TR Settlement certification system has been directly associated with all of the global goals at least once, with the exception of "SDG 5: Gender Equality." No direct relationship could be established between the criteria and SDG 5. The goals with the highest number of direct associations are "SDG 11: Sustainable Cities and Communities" (65 times), "SDG 13: Climate Action" (45 times), and "SDG 3: Good Health and Well-being" (23 times), respectively. This intensity reveals that themes such as urbanization, climate adaptation, and public health are predominant in the study. It is evident that SDG 11, which has the highest number of direct associations, promotes the creation of more livable and sustainable cities and communities.

On the other hand, the three goals with the fewest direct associations are "SDG 5: Gender Equality" (0 times), "SDG 4: Quality Education" (1 time), and "SDG 14: Life Below Water" (1 time). This indicates that while the thematic diversity is preserved, certain concepts emerge less prominently than others. When indirect impacts are taken into account, contributions to these goals can be improved through specific policies and practices. The total number of direct associations with global goals for each YeS-TR Settlement module by category is presented in Table 7.

Table 7. Global goals numbers directly related to YeS-TR Settlement modules

Theme/ SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BOL	1	0	0	0	0	0	0	0	2	2	5	0	2	0	1	3	2
AKE	0	0	4	0	0	2	4	0	3	3	12	4	10	1	4	1	0
UHA	0	0	7	0	0	1	1	1	2	2	21	1	17	0	1	0	0
KET	1	1	9	0	0	0	2	3	2	5	18	6	14	0	3	2	0
SES	1	1	2	1	0	0	0	5	2	5	6	1	0	0	0	2	0
INO	0	0	1	0	0	1	1	0	3	0	3	1	2	0	0	1	2
Total:	3	2	23	1	0	4	8	9	14	17	65	13	45	1	9	9	4

This table shows how many times each module was associated with which global goal. The findings demonstrate that all modules have the highest number of direct associations with "SDG 11: Sustainable Cities and Communities." Additionally, "SDG 9: Industry, Innovation and Infrastructure" stands out as one of the most frequently associated goals in the INO module. The prominence of this goal in the INO module reflects the emphasis placed on innovation and technological infrastructure.

When these results are evaluated overall, a direct association with "SDG 3: Good Health and Well-being" can be established due to factors such as improving air quality, ensuring walkable, accessible, and safe pedestrian pathways, and promoting an active lifestyle. The goal "SDG 11: Sustainable Cities and Communities" is strongly supported by the certification system due to its emphasis on inclusive and safe urban design, support for urban sustainability, climate adaptation, and a focus on community well-being. Moreover, contributions are made to "SDG 13: Climate Action" through the promotion of climate-resilient planning and carbon emission management. Conversely, no direct relationship exists with "SDG 5: Gender Equality." Only limited associations were established with "SDG 4: Quality Education" and "SDG 14: Life Below Water," each being directly associated only once. This indicates that contributions to certain global goals remain limited.

The fact that YeS-TR Settlement has been directly associated at least once with all global goals except "SDG

5: Gender Equality" demonstrates that the system contributes to the social, economic, and environmental dimensions of sustainability. "SDG 11," which stands out across all modules, plays a decisive role as it addresses all three dimensions of sustainability simultaneously. While YeS-TR Settlement has a broad sphere of influence regarding sustainable settlement design, it also presents opportunities for development in areas where its impact is more limited, such as gender equality and quality education.

In the existing literature, Medvedkina and Khodochenko (2019) emphasized that green buildings offer an integrated structure with social, economic, and environmental dimensions in terms of achieving the Sustainable Development Goals, and examined the aspects of green building practices that overlap with global goals [12]. Goubran et al. (2023) analyzed the alignment of green building and real estate standards with the 2030 Agenda and highlighted significant thematic intersections between these standards and global sustainability goals [13]. Likewise, studies by Goubran (2019) [14] and Illankoon et al. (2021) [15], which revealed meaningful relationships between the construction sector and the Sustainable Development Goals, support the findings of this study. In the research conducted by Wen et al. (2020), SDGs 3, 7, 11, and 12 were identified as the goals most supported by green building certification systems [16]. When compared with the present findings, the fact that SDGs 3 and 11 are among the three most supported goals indicates a strong overlap. Similarly, the study by Goubran et al. (2022) found that the LEED BD+C (Building Design and Construction) v4.1 certification system had the strongest associations with SDGs 3, 12, and 11 [17]. This also parallels the prominent trends in the current study, particularly with regard to SDGs 3 and 11, and supports the validity of the findings in the context of the literature. However, what distinguishes this study from others is the intensity of contribution to SDG 13. It can be stated that YeS-TR Settlement provides a higher level of support to "SDG 13: Climate Action" compared to the findings of the existing literature.

The strong association established with SDG 11 offers a holistic approach to addressing major urban issues in Turkey, such as unplanned development and irregular urbanization. The YeS-TR Settlement Certification System contributes to the creation of sustainable, climate-resilient, and more livable settlements. It can be asserted that YeS-TR Settlement serves as an effective tool for achieving global goals and their social, economic, and environmental objectives. The establishment of linkages with the SDGs within the scope of this study demonstrates that the national system contributes to global sustainability. By promoting green transformation through national certification systems in the Turkish construction sector, building professionals and users can be made more aware of sustainability issues. This is particularly important for fostering sustainable urbanization in Turkey and for advancing progress toward the global goals.

This study was conducted within a theoretical framework based on interpretive methodology. Accordingly, the evaluations presented are made by considering only direct relationships and are open to alternative interpretations. Future studies employing different methodological approaches may contribute to the comparative assessment of the present findings. Through the analyses conducted, the SDGs associated with each module were identified, and the strengths and weaknesses of the certification system were revealed.

Conclusion

In this study, it was identified that the criteria of the YeS-TR Settlement certification system are directly related to various SDGs. An examination of the direct relationships established between the criteria and the goals reveals that, except for "SDG 5: Gender Equality," all other goals are associated with at least one criterion. This indicates that YeS-TR Settlement supports the three dimensions of sustainability;

social, economic, and environmental. It is evident that the certification system particularly aligns with themes such as urban resilience, climate action, and health and well-being. Accordingly, "SDG 11: Sustainable Cities and Communities," "SDG 13: Climate Action," and "SDG 3: Good Health and Well-being" stand out as the goals with the highest number of direct associations. The global goal with which the YeS-TR Settlement certification system establishes the strongest connection, "SDG 11: Sustainable Cities and Communities," is directly related to all modules. On the other hand, the system is less directly associated with goals such as "SDG 5: Gender Equality," "SDG 4: Quality Education," and "SDG 14: Life Below Water." This situation suggests that while the system is strongly linked to environmental and urban development objectives, there is a need for improvement in addressing social aspects, particularly in areas such as quality education and gender equality. The findings demonstrate that the certification system can be considered an effective tool in achieving the SDGs. Promoting the widespread use of YeS-TR Settlement and increasing public awareness in this field are of great importance to accelerate progress toward global goals and to take concrete steps in addressing climate change.

The findings of this study are in line with the existing literature on the relationships between settlement-scale certification systems and the SDGs. It is believed that YeS-TR Settlement has the potential to more effectively transform the Turkish construction sector, as it is more suitable for local conditions, more accessible, and more cost-effective. As the findings suggest, YeS-TR is likely to play an active role in ensuring urban-scale sustainability and in creating more livable communities, particularly through its contributions to SDG 11. In order to better understand and evaluate the system's impact, it is recommended that future research support the findings of this study with different methodological approaches and empirical case studies.

In the study, the direct relationships identified through qualitative content analysis (using the document analysis technique) and conceptual matching were visualized through tables. Nevertheless, alternative analytical methods could be employed to obtain more quantitative data. This qualitative conceptual matching highlights the importance of integrating local sustainability tools with global agendas. The study aims to establish a foundation for future research and to support the inclusion of national green certification systems within the global sustainability framework. This would contribute to the development of sustainable settlement policies in Turkey. Additionally, by bringing these topics to the agenda through green building experts and climate activists, planners and users in Turkey can be made more aware of these critical issues.

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Greenhouse Gas Emission Inventory And Carbon Footprint Analysis In The Automotive And Supplier Industry Sector

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ABSTRACT

This study was carried out to reveal the corporate carbon footprint of a facility operating in the automotive and sub-industry sector and to develop greenhouse gas management policies. Greenhouse gas (GHG) emissions from the facility's activities in 2023 were determined within the scope of Scope 1, 2 and 3 categories based on ISO 14064-1:2018 and the GHG Protocol. An inventory was created by detailing Scope 1 (direct), Scope 2 (indirect energy source) and Scope 3 (other indirect) emissions; primary data was provided by the company, and secondary data was provided by IPCC, DEFRA and Ecoinvent 3.9 databases. The results of the study showed that the total emission of the facility for 2023 year is 30,575.71 t CO_2e. It was observed that the facility's total emissions were mostly in category 4 with a rate of 79%, followed by category 2 emissions with a rate of 10%.

Key words: carbon footprint, sustainable development, climate change, greenhouse gas emissions

Introduction

Global warming and the resulting global climate change has become one of the most important threats to human development today Climate change causes losses and damages to ecosystems and people, increases negative impacts on agriculture and food production, and makes economic growth difficult It is accepted that the main cause of global warming and related climate change is the gases called greenhouse gases (GHG) that trapping heat in the atmosphere. Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Fluorinated gases are leading GHG that related with human activities. It has been reported that human activities are responsible for nearly all of the rising in GHG in the atmosphere over the last 150 years.

Industrial activities and the energy production required for these activities have significant impacts on the environment. It is reported that industry is responsible for more than one-third of global primary energy consumption and energy-related carbon dioxide emissions, and industrial energy use is estimated to increase at an annual rate of between 1.8% and 3.1% over the next 25 years .Reducing the environmental impact of industrial activities is a fundamental element of combating climate change and sustainable development. All sectors involved in industrial activities have important responsibilities in controlling the observed and projected effects of global warming and related climate change and in achieving the international goals set for a sustainable planet. In this context, monitoring and reporting greenhouse gas emissions, especially in energy-intensive sectors, is of critical importance, and carbon footprinting is an important tool that can be used for this purpose.

Carbon footprint is a technique to measure the amount greenhouse gas released into the atmosphere directly or indirectly as a result of activities such as energy consumption and transportation of individuals and organizations, in terms of carbon dioxide equivalent. This allows assessing the climate change impact category associated with products, services, processes or an organization As a result of international climate-related efforts and growing consumer awareness, there has been increasing interest in determining corporate-level carbon footprints. International standards and guidelines such as the Greenhouse Gas Protocol (WRI 2004; WRI 2011), ISO 14064 (ISO 2019) are used in corporate carbon footprint calculation.

Implementing carbon footprinting at the corporate level can be beneficial for businesses in many ways, including identifying their role in climate change, defining greenhouse gas management policies and strategies, energy efficiency, compliance with legislation, improving their corporate image.

Among industrial activities, the automotive sector is one of the most important, providing direct or indirect employment for millions of people worldwide and having suppliers in a wide range of industries, including metal, plastics, glass, and electronics.Therefore, determining the environmental impacts of this sector and making necessary improvements in areas such as energy, technology, vehicles, equipment and business planning are of great importance for a sustainable future.

The aim of this study is to reveal the corporate carbon footprint of a facility operating in the automotive and sub-industry sector and to develop greenhouse gas management policies.

Method

The study was based on the ISO 14064-1:2018 standard and the Greenhouse Gas Protocol (GHG Protocol).
In GHG Protocol emissions are divided into three scopes.
Scope 1: Direct GHG emissions arising from activities that are owned or controlled by the organization
Scope 2: Indirect GHG emissions based on purchased electricity and other energy sources
Scope 3: Indirect GHG emissions from supply chain activities and downstream activities

ISO 14064-1 standard categorizes emissions and removals into 6 categories.
Category 1: Direct GHG emissions and removals
Category 2: Indirect GHG emissions from imported energy.
Category 3: Indirect GHG emissions from transportation.
Category 4: Indirect GHG emissions from products and services used by organization. (ISO
Category 5: Indirect GHG emissions associated with the use of products from the organization.
Category 6: Indirect GHG emissions from other sources

In this study emission calculations were made within the scope of Scope 1, 2 and 3 categories. An inventory was composed by detailing Scope 1 (direct), Scope 2 (indirect energy sources), and Scope 3 (other indirect) emissions. Primary data were obtained from units within the enterprise and covers data between 01.01.2023 and 31.12.2023. Secondary data were obtained from IPCC 2006, DEFRA and Ecoinvent 3.9 databases. The methodology used is an account-based method and is supported by relevant standard methods. Some indirect emission sources were excluded from the inventory due to lack of data or insignificance of emission impact (e.g. visitor transportation, some services).
Emissions are calculated using the following general formula:

Emissions ($kgCO_2e$) = Activity Data × Emission Factor × Global Warming Potential

Main Results

The results of the study are presented at the Table 1. The results showed that the total emission of the facility for 2023 year is 30,575.71 t CO2 e. It was observed that the facility's total emissions were mostly in category 4 with a rate of 79%, followed by category 2 emissions with a rate of 10%.

Table 1. GHG emissions

Emissions	Total CO_2-e	%
Category 1	655,87	2
Category 2	2.927,53	10
Category 3	2.220,19	7
Category 4	24.06,20	79
Category 5	755,93	2
Category 6	0,00	0

In a study conducted by Dindar G., the carbon footprint of a company operating in the automotive supply industry, using 2019 and 2020 data obtained from company and Tier 1 approach, was calculated. The carbon footprint arising from fuels used for heating, electricity consumption, water consumption, waste generation, wastewater generation, and personnel or service vehicles provided by subcontractor services has been determined. The results showed that GHG was 16,501 tons in 2019 and 12,921 tons of CO_2 equivalents in 2020

Park et al., 2024 calculated the direct and indirect GHG emissions of the Korean automobile industry for 2017 year. The results revealed that Korean automobile industry is responsible from 8.4% of national GHG emissions in 2017. Scope 1, Scope 2, and Scope 3 emissions were 3.0%, 2.9%, and 94.7%, respectively

In a study performed by Lee, K-H., carbon footprint of automobile supply chain management was investigated. Especially, Scopes 1, 2, and 3 of the carbon footprint boundary were implemented at selected key suppliers and automobile industry. The in-depth case study of the front bumper product showed that 18% of the carbon footprint can be attributed to the raw material stage, 70% to the in-house production stage, and 12% to the distribution stage

In a study conducted by Ediz SB., carbon footprint from part production activities in the automotive supplier industry was evaluated. The average annual average emission was calculated as 250 328 tons of CO2 eq. According to emission calculations, purchased raw materials account for 95.1% of emissions, electricity consumption accounts for 3.7%, post-production logistics and transportation activities account for 1.0%

Conclusion

The inventory created allowed the business to identify greenhouse gas sources and develop reduction strategies. The main strategies suggested for reducing emissions are:
- Renewable energy investments

- Energy efficiency projects
- Use of low-carbon emission equipment
- Sustainable transportation and supply chain solutions

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Contribution Of Legal Structures Of Actors In Supply Chains To Risk Resistance: Comparison Of Companies and Co-Operatives

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ABSTRACT

It has been observed that businesses that have good relations with their suppliers can easily pass difficult processes (1). With globalization, supply chains have become longer, but with technology, time has become shorter. This has made supply chains weaker against risks (1).
Floods occurred in 2021. Damage worth $18.4 billion occurred in the People's Republic of China (PRC), while an unprecedented flood occurred in Pakistan. It affected approximately 33 million people in 2022, with estimated total damages exceeding $14.9 billion (11). These events not only directly put lives and property at risk, but also cause greater indirect supply chain and business disruptions (12).
In this study, the contribution of their legal structures of the actors to risk resistance will be investigated, while the comparison of selected company and cooperative structures will be investigated. The research was planned in two stages. In the first stage, in order to determine the importance of risks, the managers of 2 sample businesses will be contacted by face-to-face interview method, the risk type will be asked as an expression, and the relationship between demographic factors and risk perceptions will be examined with T test and ANOVA. In the second stage of the research, an attempt will be made to measure the effects of the actors' roles and legal structures in the supply chain on supply chain risk factors with a new scale developed as a result of the ranking of the risks obtained from the first stage. Face-to-face interviews, T-test and MANOVA will be used, the research model analyzed using the structural equation modeling path analysis method, studies related to the thesis topic in the last 20 years will be examined, a conceptual research model will be created in the light of data obtained from the literature.

Key words: Supply Chain Management, Risk Factors, Legal Structure.

Literature Review

Agricultural and food production, which are directly related to human health, the environment, and the economy, are among the core areas of activity of countries and various international organizations. The entire world is integrating food security and safety into its legal regulations and policies while determining various strategies in the field of food security and safety.

Food security and safety are threatened by the confluence of many current problems. Measures taken through various global collaborations are essential to ensure food security and safety. Otherwise, access to sufficient, healthy, and safe food will become increasingly difficult in the near future, and various diseases and hunger will spread rapidly (16).

The main reasons for the failure to achieve food security at the desired level include climate change, low agricultural yields, and increased biofuel production, along with fluctuations in supply, price increases, falling income levels, institutional problems, and poorly implemented policies (17). According to the EIU (The Economist Intelligence Unit): The underlying causes of food security problems are rising energy prices, declining agricultural investments, economic growth, rising incomes, rising prosperity, and increasing food demand due to population pressures, trade-distorting subsidies, biofuels, and ecological degradation (18).

FAO’s annual “State of Food Insecurity in the World (SOFI)” reports are noteworthy for their ability to reveal the food security and safety status of various countries and regions, the work being done in these areas, and future expectations. According to SOFI 2015, approximately 795 million people are currently undernourished. The decrease in the share of undernourished people in the total population from 23% to 12.9%, despite rapid population growth, has been noted as a positive development (19).

Sub-Saharan African countries, in particular, are countries experiencing food shortages, where malnutrition is most prevalent, epidemics are frequently encountered due to adverse environmental conditions, and where unemployment and migration are high. In fact, this region has the lowest score in the GFSI (37.8). The reasons for the lack of food security and safety in the region are cited as rapid population growth, inadequate agricultural infrastructure development, low income levels, and insufficient consumption of quality proteins. An examination of the “World Governance Indicators” prepared by the World Bank reveals that the governments of the countries in this region are weak in controlling corruption and improving government effectiveness, and this has a negative impact on food security and safety (20). Despite these negativities, the Growth and Development Strategy implemented in Malawi 2011–2016 identified food security as a priority, and food insecurity in the country has been significantly reduced by implementing policies aimed at increasing agricultural productivity, ensuring access to food, and reducing poverty (21). FAO’s recommendations for ensuring food and nutrition security in Sub-Saharan Africa are as follows: Political leadership and management effectiveness, effective policy development in the food and agricultural sectors, improved macroeconomic environment, and inclusive economic growth (22).

According to Vermeulen et al. (2012), agriculture and food production systems account for 19% to 29% of global greenhouse gas emissions. Modern agricultural production systems use agricultural chemicals such as fertilizers and pesticides, and fossil fuels for energy machinery, which increases the environmental friendliness of food production. Furthermore, energy and water demand for food processing systems also play a significant role. The purchasing function can be considered a strategic issue in businesses. The relationship between buyers and suppliers is crucial, especially in manufacturing businesses. When the relationship between buyers and suppliers is long-term, a company’s supply chain provides an advantage over its competitors (23).

A supply chain is a network of organizations that collaborate with each other to improve the flow of materials and information between suppliers and customers at lower costs and at the highest speed. The goal of the supply chain is to ensure maximum customer satisfaction. The term “network” in this definition is possible only by defining and implementing an internal policy that governs not only the complementary activities of companies within the supply chain but also the relationships among companies within this chain that carry out the same activities. The purpose of this internal policy also includes the competition between workloads and benefits. The definition also emphasizes that the supply chain is a global organizational network where participants collaborate with each other and states that the supply chain must have a unique structure and strategy. Such an integrated system requires each supplier to manage its own needs.

To ensure fairness for supply chain participants, these gains and losses must be shared fairly among them. Otherwise, internal disputes can weaken the supply chain and lead to its disappearance (25).

Increased competition in world markets is inevitable with globalization. Trade, which has gained international dimension, also causes commercial relationships to become complex and intense. In this regard, it can be said that businesses can easily navigate challenging supply chain processes by establishing strong relationships with their suppliers.

In today's globalized environment, supply chain management plays a vital role in helping organizations compete and integrate with global economies. In a supply chain, a large amount of information and various product flows are managed at all stages. In this context, businesses deliver the right amount, to the right place, at the right time, with minimal cost, and with maximum customer service. However, as with any system, the supply chain is exposed to various types of upstream and downstream risks (1). These risks can arise from internal organizational activities, such as distribution disruptions or security breaches, or from external sources such as natural disasters, economic crises, epidemics, also known as pandemics, or terrorist attacks. These types of unexpected events have the potential to disrupt the flow of materials or products throughout the supply chain from suppliers to end consumers (13).

An effective supply chain prevents companies from encountering negative situations such as high costs, order delays, incorrect product orders, and incorrect order quantities due to supply chain-related issues. These problems not only impose a significant cost burden on the company but also impact the company's brand value in the eyes of consumers who offer its services or products (26). From this perspective, effective supply chain management can reduce a company's costs and increase its brand value. In the developing global economy, competition between businesses is increasing, and businesses strive to maximize their profits while also aiming to achieve the highest customer satisfaction. The highly competitive environment created by globalization, especially after the 1980s, has made supply chains crucial for the success and profitability of businesses.

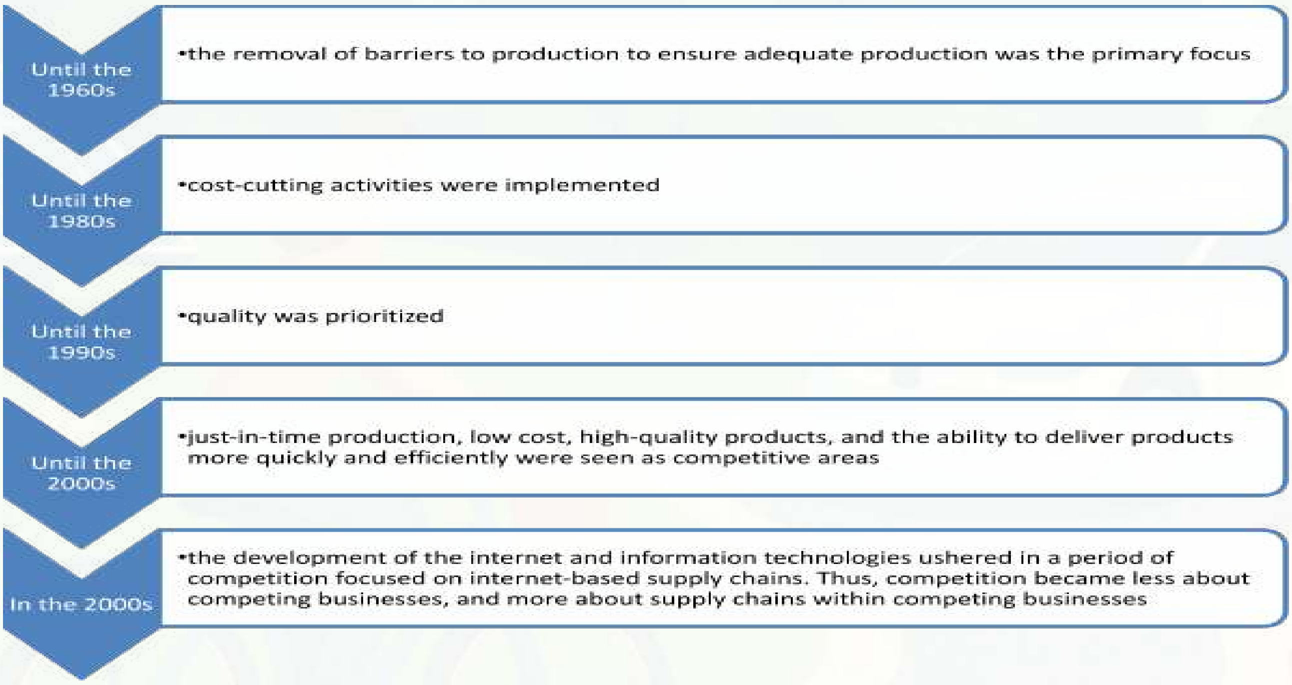

Figure 1. Periodic grouping of the competitive areas of the businesses (27).

Supply chain efficiency is crucial for product competition in markets, food supply security, and producer-consumer welfare. This study can be considered unique for these reasons.

Supply chain efficiency is closely influenced by marketing margin. While it is generally believed that the widening gap between producer and consumer prices stems from wholesale markets, this is actually a consequence of developed economies. Indeed, in developed economies, improvements and increases throughout the entire supply chain, including processing, packaging, marketing, and consumer delivery, lead to increased marketing margin. As can be seen in Table 1, the marketing margins of the main products identified in the study are shown in comparison with developed countries. Accordingly, when examining the United States (US), France, Australia, and Japan, the rate of change between producer and consumer prices ranges from 200-322%, while in Türkiye, this rate ranges from 150-180%. This is also observed in staple food products (meat, sugar, rice, etc.). While the change rate in selected developed economies was 221.98-299.29%, the average in Türkiye was 148.37% (28).

When examining Australia and Japan, the change rate between producer and consumer prices ranged from 200-322%, while in Türkiye this rate was between 150-180%. This situation is also observed in staple food products (meat, sugar, rice, etc.). While the change rate in selected developed economies was 221.98-299.29%, the average in Türkiye was 148.37% . Therefore, to identify areas for supply chain improvement, it is necessary to examine all actors in the chain (28).

Table 1: The marketing margins of the main products and staple food products

Produce	USA												Japan							
											Absolute									
Tomato	1,26	4,30			0,89	2,36			1,11	3,98	2,87		2,66	5,07						
Pepper	0,93	3,68			1,12	3,23			1,19	3,45	2,26		2,28	8,56						
	0,65	2,46			0,99	2,59			1,42	4,23	2,81		2,64	7,99						
Zucchini	0,32	1,56			0,78	2,88			0,65	3,11	2,46		1,68	6,56						
Eggplant	0,68	2,22			0,95	2,59			1,25	3,65	2,40		3,22	11,23						
Potato	0,21	1,94			0,38	1,22			0,42	2,63	2,21		1,21	2,34						
Onion	0,32	1,50			0,32	1,09			0,43	2,25	1,82		0,95	3,46						
Banana	0,65	2,24			0,45	1,45			1,19	1,88	0,69		1,12	2,79						
Apple	0,85	3,34			0,73	1,06			1,42	3,38	1,96		2,82	5,78						
Lemon	0,67	2,22			0,69	1,84			0,98	2,22	1,24		1,00	4,29						
Pear	0,61	1,98			0,65	1,74			0,56	2,56	2,00		4,82	12,33						
Peach	1,58	3,46			1,70	2,99			1,67	4,23	2,57		6,31	18,65						
Orange	0,76	4,00			0,72	3,12			0,93	2,82	1,89		1,14	4,98						
	0,96	4,22			0,98	3,31			1,47	4,56	3,09		2,31	5,85						
Red Meat	9,56	26,38	252,19		2,69	10,30	27,71		4,57	17,73	80,96		4,21	18,55	78,10		3,33	8,70	29,00	
Milk	0,55	1,93	1,06		0,23	0,90	0,20		0,54	1,61	0,87		0,54	1,84	0,99		0,40	0,89	0,36	
Egg	0,84	3,32	2,79		0,76	2,99	2,26		1,64	4,81	7,89		0,65	1,99	1,29		0,97	1,95	1,89	
Rice	0,98	3,62	3,55		0,45	1,53	0,69		0,41	1,50	0,62		1,37	4,75	6,48		0,33	0,96	0,32	
Sugar	0.21	1,14	0,24		0,22	0,89	0,20		0,53	1,43	0,76		0,53	1,54	0,82		0,23	0,65	0,15	
Fksir	0,26	1,31	0,34		0,32	0,99	0,32		0,18	0,94	0,17		0,79	1,61	1,26		0,33	0,92	0,31	
Oil	0,88	3,14	2,76		0,95	2,50	2,39		1,29	3,98	5,13		1,10	3,55	3,91		1,20	2,53	3,04	110,3

In addition to competition and protective policies in the global economy, the COVID-19 pandemic and regional political crises have also led to an upward trend in food prices. With increasing prosperity, especially in economies with increasingly dense and growing populations, demand for food products has increased. Yield losses due to climate change, rising input costs, and the emergence of monopolistic structures have led to rapid increases in product prices. A similar situation applies to the Turkish economy. Since 2003, thanks to structural and economic reforms, consumer demands and tastes have changed, production technology has been updated, and household consumption habits have also shifted (28).

The actors in the supply chain are decisive in its effectiveness. Indeed, while the supply chain can be managed holistically from a single center, it can also be achieved through the complementarity of many actors. Indeed, different legal entities, such as companies or cooperatives, operate at each stage of the supply chain. These structures can be involved not only in the marketing of agricultural products but also in the marketing of all products. As a matter of fact, relevant institutions, especially the competition authority, closely monitor the market share of these and similar structures and their market-distorting effects on the supply chain in order to protect competition.

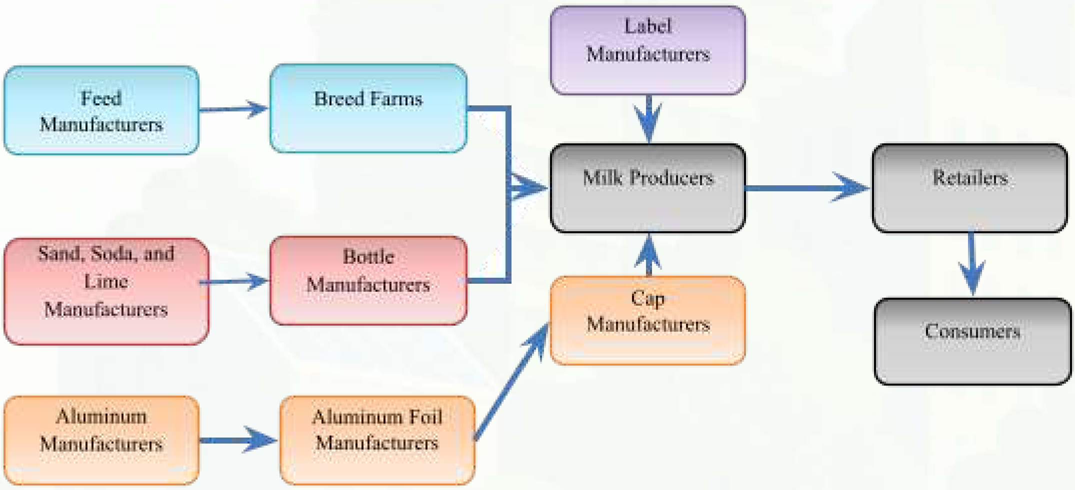

Figure 2: Supply Chain Model

There are various practices for the direct marketing of agricultural products in agricultural marketing (31) (32). The most preferred types of direct marketing in the marketing of agricultural products are: Pick-Your-Own, Farmers' Markets, the Internet, Direct Sales to Restaurants and Institutions, Community Supported Agriculture, and Participation in Agro-Tourism Activities.

Agricultural marketing cooperatives are an important form of organization in the agricultural sector. For example, in the United States, marketing cooperatives are dominant throughout the country, and 86% of dairy products, 41% of cotton, and 40% of grain and cooking oil are distributed by cooperatives (33). Grain, cooking oil, dairy products, fruits, vegetables, etc., marketed through marketing cooperatives. The overall value of agricultural products in Canada is $14.24 billion (34). In Europe, 60% of produce is harvested, transported, and marketed by agricultural cooperatives (35). In Denmark, the Netherlands, and Belgium, even 70-80% of fruits and vegetables are marketed through cooperatives. Furthermore, marketing cooperatives are an indispensable organizational form in Asian countries such as Japan and Korea (36).

With the acceleration of marketization in China in the 1990s, and particularly with the publication of the "Farmers' Cooperatives Law" on July 1, 2007, farmer cooperatives experienced rapid development. By the end of 2009, there were 246,400 farmer cooperatives, a 122.2% increase compared to 2008. 52.8% of these farmer cooperatives are marketing cooperatives. As of the end of March 2, 2012, there were 525,000 farmer cooperatives in China. Farmer cooperatives cover a variety of products, including cereals, oilseeds, vegetables, and fruits. It is estimated that by the end of the 12th Five-Year Plan, the value of products sold by cooperatives will exceed 30% of the gross value of agricultural production in China (37).

There are 599 marketing cooperatives in Greece. Furthermore, there are 1,225 recognized Producer Organizations (POs) and 497 Producer Groups (PGs), including 737 in the Fruit and Vegetable (F&V) sector (POs and PGs) (38). These organizations comprise the majority of Greek producers (123,249 fruit and vegetable producers/228,288 producers, or 54% of Greek producers). Therefore, agriculture is an important sector in Greece. A national report on Greece (39), examining data from the fruit and vegetable sector from 2005 to 2011, concluded that producers are the most vulnerable link in the fruit and vegetable supply chain, while wholesalers are the most favored.

Marketing cooperatives in the food and beverage sector in Greece are generally weak, with only a few exceptions. One such exception is the Venus Growers cooperative in the Imathia prefecture in northern Greece (40). However, many producers in this region are hesitant to join cooperatives. Despite the internal and external challenges faced by producers and cooperatives, various studies indicate that Greek consumers purchase cooperative agricultural products primarily because they want to help Greek producers and local economies, secondly because they recognize their superior quality, and thirdly, because they recognize and support the regulatory role of cooperatives (41) (42). This study will investigate the contribution of the legal structures of actors in supply chains to risk resilience and examine the resilience of selected corporate and cooperative structures to market risks.

A limited number of studies addressing supply chain risk types have been found in the literature. The review of these studies reveals that some simply define risk types without any classification (43), while others classify specific risk types under specific categories (44).

Different classifications have been made by different authors and organizations in the literature, addressing aspects such as the source, impact, and frequency of occurrence of supply chain risks. Some studies have divided risk types into two categories: internal and external (45), (46), and operational and disruptive (44). In addition, some studies have classified risk types into three categories using a similar approach but different terminology (47) (48). These three categories can be classified as organizational risk or internal risk, network-related/supply chain risks, and environmental risks or external environmental risks.

The World Economic Forum (49) conducted a study on global risks, classifying risk types into four categories and presenting their prevalence rates. The Forum also focused on supply chain risks.

The study categorized environmental risks into four categories: natural disasters (59%), adverse weather conditions (30%), epidemics (11%), geopolitical risks (conflict and political instability (46%), import/export restrictions (33%), terrorism (32%), corruption (17%), illicit trade and organized crime (15%), piracy (9%), nuclear/chemical/biological weapons (6%)), economic risks (sudden demand shocks (44%), product price fluctuations (30%), customs disruptions (26%), exchange rate fluctuations (26%), global energy bottleneck (19%), property/investment restrictions (17%), labor shortages (17%)), technological risks (information and communication disruptions (30%), transportation infrastructure deficiencies (6%)).

Kar (50) categorized risk types into five categories: environmental risks, industrial risks, organizational risks, site-specific risks, and decision-maker-related risks, according to Maclean-Bristol (51) classified supply chain risks into six categories: social risks, legal risks, political risks, economic risks, technical risks, and environmental risks.

Unlike the studies above, only two studies have classified supply chain risk types based on the degree of their negative impact on companies (44) and (52). Ravindran et al. (52) emphasized that macro risks are similar to disruption risks (44) and value-at-risk (VaR) (52), while micro risks are similar to operational risks (44) and miss-the-target (MtT) (52).

The most comprehensive classification in the literature was made by Ho et al. (53). Based on an evaluation of previous studies, the authors determined that supply chain risks can be divided into two basic categories: macro and micro risks (catastrophic and functional according to Sodhi et al. (54); disruptive and functional according to Tang (44).

Macro risks refer to negative and relatively rare external events and circumstances that can have negative impacts on companies. Macro risks include natural disasters (e.g., earthquakes, climate disasters) and human-induced risks (e.g., war, terrorism, and political instability).

Micro risks, on the other hand, refer to relatively recurring events that arise directly from the relationships of stakeholders throughout the supply chain and/or from the internal activities of companies. Generally, macro risks have a greater negative impact on a company than micro risks. Micro risks can be categorized into four subcategories: demand risks, production risks, supply risks, and infrastructure risks. Demand and supply risks refer to negative situations arising from stakeholders in a company's inbound and outbound supply chain network, respectively. Production Risks refer to negative events and situations that affect a company's internal capabilities, such as product and service production, quality and on-time production, and profitability (53).

Information technologies, transportation, and financial systems are also critical for a supply chain to function properly. Any disruption in these systems can cause serious problems in a supply chain. Ambulkar et al. (56), in their study using a survey to identify supply chain risk sources, found that out of 199 interruption events, 62 were caused by supply interruptions, 42 by logistics/delivery interruptions, 44 by internal company/production interruptions, and 51 by environmental factors such as natural disasters, legal, and political issues. The table below summarizes the classifications mentioned above.

Table 2. Publications list categorized by supply chain risk types

Publications	Supply Chain Risk Types
Jüttner et al.	Environmental risks, network risks, organizational risks
Cavinato	Physical risks, financial risks, information risks, relationship risks, innovation risks
Chopra ve Sodhi	Disruptions, delays, system risks, forecast risks, intellectual capital risk, supply risk, receivables risks, inventory risks, capacity risks
Christopher ve Peck	Risks internal to the company: process and control risks Risks external to the company and internal to the supply chain: demand and supply risks Risks external to the supply chain network: environmental risks
Tang	Operational risks: uncertain customer demand, uncertain supply, uncertain cost Disruption risks: earthquakes, floods, storms, terrorist attacks, economic crises, exchange rate fluctuations, strikes
Wu et al.	Internal risks: internal controllable risks, internal partially controllable risks, internal uncontrollable risks External risks: external controllable risks, external partially controllable risks, external uncontrollable risks

Blackhurst et al.	Disruptions/disasters, logistics risks, supplier dependency risk, quality risk, information systems risk, forecast risk, legal risks, intellectual capital risk, supply risk, receivables risk, inventory risks, capacity risks, administrative risks, security risks
Maclean-Bristol	Social risks, legal risks, political risks, economic risks, technical risks, environmental risks
Manuj ve Mentzer	Supply risks, operational risks, demand risks, security risks, macro risks, political risks, competitive risks, resource risks
Tang ve Tomlin	Supply risks, process risks, demand risks, intellectual capital risk, behavioral risks, political/social risks
Trkman ve Mc Cormack	Internal risks: market and technology fluctuations External risks: discrete events (terrorist attacks, epidemics, strikes) and continuous events (inflation rate, CPI change rates)
Ravindran et al.	Value-at-Risk (VaR): Strikes, terrorist attacks, natural disasters Miss-Target (MtT): late delivery, missing quality requirements
Waters	Physical risks, financial Risks, information risks, organizational risks
Tang	Material flow risks (supply, production, delivery), financial flow risks, information flow risks
Manuj ve Dittman	Traditional risk sources: political risks, customs risks, financial risks New risk sources: cost risk, quality risk, lead time risk, security risk
WEF	Environmental risks, geopolitical risks, economic risks, technological risks, societal risks
Ho et al.	Macro risks: natural disasters and human-induced risks. Micro risks: demand risks, production risks, supply risks, and infrastructure (information technology, transportation, and financial systems) risks

Methodology

1. Literature Review
2. Formulation of Hypotheses
3. Method Used to Obtain Data
3.1. Creation of the Data Collection Tool
3.2. Conducting the Preliminary Survey
3.3. Finalizing the Survey Form
3.4. Data Collection
4. Method Used to Analyze Data
4.1. Identification and Classification of Risk Factors Based on Literature
4.2. Review of PANAGRO Inc.'s Supply Chain
4.3. Review of SÜTAŞ Inc.
5. Conducting Statistical Analyses
6. Evaluation of Results

The research was conducted through the following steps: literature review, determination of hypotheses based on literature, collection of data related to the hypotheses, and analysis of these data. The roadmap and stages of the research are presented below.

Main Results and Discussion

In this study, the comparison of selected company and cooperative structures will be investigated while investigating the contribution of the legal structures of the actors in the supply chains to risk resilience.
Within this scope, the research consists of two stages. As a result of the first stage, a new scale will be developed that identifies the impact of actors' legal structures on supply chain risk factors by ranking them according to their scores.

In the first stage, managers of two sample businesses will be contacted through face-to-face interviews to determine the severity of risks. They will be asked to express their risk types, and the relationship between demographic factors and risk perceptions will be examined using a t-test and ANOVA. At the end of the first stage, risk factors will be ranked according to their scores. For this purpose, managers of one selected company and one cooperative will be asked about the risks affecting them in the supply chain, which have been previously identified from the literature as risk types. Questions prepared to determine risk perceptions will be directed to all managers of the businesses, especially those involved in the supply chain. Based on the results, risks will be ranked according to their scores. In the second stage, after identifying the risks, the impact of actors' legal structures on supply chain risk factors will be assessed.
Data for the study will be collected through face-to-face interviews using surveys. In light of the data obtained, the impact of actors' legal structures on supply chain risk factors will be analyzed using structural equation modeling. A T-test and MANOVA will be used to examine the relationship between demographic factors and the impact of actors' legal structures on supply chain risk factors. The research model will be analyzed using structural equation modeling path analysis.

It is believed that the data obtained from the analyses will help businesses consider the impact of actors' legal structures on supply chain risk factors, enabling them to take the necessary precautions and take more controlled and beneficial steps. Furthermore, one of the distinguishing features of this research from other studies is that the risks were not directly derived from pre-existing risks in the literature, but were generated by directly asking companies. A review of the literature reveals that all studies conducted within a similar framework utilize pre-determined risks. The study's application to a company or cooperative legal structure also makes the study unique. A literature review conducted during the development of the data collection tool for measuring the impact of actors' legal structures on supply chain risk factors in supply chain management revealed that no study had yet addressed the research topic holistically.

Conclusion

The draft conceptual model developed using data obtained from the literature review conducted prior to the research is shown below. The research model was examined under a total of eight variables, including four factors for legal structure and four factors for supply chain risks. The model fundamentally demonstrates that the legal structures of actors in the supply chain affect risk resilience. In this context, the first stage of the research argues that demographic factors may influence the determination of supply chain risks, while the second stage argues that demographic factors will similarly influence the variables included in the model.
The characteristics of the eight variables examined within the research model are listed below.
First variable: Private enterprises; refers to individuals/institutions established by one or more individuals or legal entities, and possesses the characteristics of merchants and businesses as defined in the Turkish Commercial Code under certain conditions.
Second variable: Public enterprises; refers to enterprises whose capital is wholly or largely owned by public legal entities.
Third variable: Cooperative enterprises; According to Law No. 1163 on Cooperatives, this structure is defined as partnerships with variable partnerships and variable capital established by real and legal persons to provide and protect their members' specific economic interests, especially their professional and livelihood needs, through mutual aid, solidarity, and surety, with the contribution of their labor and money.
Fourth variable: Other; refers to a person/institution not included in the definitions above.
Fifth variable: Economic risks in the supply chain; factors such as excessive decreases or increases in inflation, delays or non-payment, excessive indebtedness of the business, exchange rate fluctuations, and decreased profits represent economic risks.

Sixth variable: Operational risks in the supply chain; operational risks include planning errors, customer dissatisfaction, decreased business performance, inadequate product or service quality controls, and product or service interruptions.
Seventh variable: Geopolitical risks in the supply chain; Geopolitical risks include political unrest, import and export restrictions, the production of counterfeit goods, fraud, corruption, and theft, and collateral insecurity.
The eighth variable: Environmental risks in the supply chain. Environmental risks include the possibility of fire, terrorist attacks, civil or racist wars, the use of chemical, nuclear, biological, and radiological weapons, and the possibility of an earthquake.
The hypotheses to be tested in line with the objectives of the research are stated below.
Hypotheses regarding the relationship between the legal structure of the actor and supply chain risk factors.
H1a: Private enterprises negatively predict economic risks.
H1b: Private enterprises negatively predict operational risks.
H1c: Private enterprises negatively predict geopolitical risks.
H1d: Private enterprises negatively predict environmental risks.
H2a: Public enterprises negatively predict economic risks. H2b: Public enterprises negatively predict operational risks.
H2c: Public enterprises negatively predict geopolitical risks.
H2d: Public enterprises negatively predict environmental risks.
H3a: Cooperative enterprises negatively predict economic risks.
H3b: Cooperative enterprises negatively predict operational risks.
H3c: Cooperative enterprises negatively predict geopolitical risks.
H3d: Cooperative enterprises negatively predict environmental risks.
H4a: Other enterprises negatively predict economic risks.
H4b: Other enterprises negatively predict operational risks.
H4c: Other enterprises negatively predict geopolitical risks.
H4d: Other enterprises negatively predict geopolitical risks.
SEM applications, which have become increasingly important and frequently used in social and behavioral sciences in recent years, have begun to become an integral part of a large number of scientific studies. SEM is a powerful statistical analysis method that allows testing multiple, interdependent relationships simultaneously. Unlike other multivariate analyses, SEM allows testing separate but interdependent multiple regression equations simultaneously within a structural model. As with multiple regression analysis, SEM allows testing the direct and indirect effects of variables in the model (14), (15). In this context, SEM will be used as the research method.
During the research, studies conducted in the last 20 years related to the thesis topic will be examined. In the literature review section, chi-square analyses will be conducted on the distributions based on publication year, publication type, publication sector, publication method used, and the publication's structural characteristics. Furthermore, a conceptual research model will be developed based on the data obtained from the literature.
The survey technique, a quantitative research method, was used in the research. The main goal of quantitative research methods is to produce information that is as objective, non-subjective, explains cause-and-effect relationships, and is generalizable from the sample to the population. The "Risks Encountered in the Supply Chain" scale will be used as the data collection tool in the first stage, and in the second stage, the "Risks in the Supply Chain" scales of the "Legal Structure of Actors" will be used. The "Risks Encountered in the Supply Chain" scale used in the first stage was created by knowing the risk type from the risks found in the literature. The "Supply Chain Risks" scale used in the second phase will be developed using face-to-face interviews and surveys conducted with managers of participating businesses in the first phase of the study. Thus, a new scale will be developed for use as the first scale in the second phase of the study. For the second phase of the study, the second scale will measure the level of supply chain integration of participating businesses, and the third scale will measure the level of supply chain performance of these same businesses. Participants will respond

to the statements in the scales using a seven-point Likert-type scale, ranging from 1 to 7: (1) Strongly Disagree (2) Disagree (3) Somewhat Disagree (4) Undecided (5) Somewhat Agree (6) Strongly Agree (7) Strongly Agree. After the collected data is transferred to the computer, all analyses of the first survey, conducted to identify supply chain risks in the first phase, will be conducted using the statistical analysis package SPSS. In the second phase, analyses of the second three-scale survey will be conducted using SPSS, and AMOS for the SEM analysis.

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Smart Cities and Digital Divide: A Social Equity Discussion

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ABSTRACT

This paper examines how smart city projects address the digital divide while integrating citizens into their systems. Smart city initiatives escalated with the significant adoption of Internet of Things (IoT), information and communication technologies (ICTs), and artificial intelligence (AI) in urban systems. Although these technologies are optimized as an innovative response to increasing urbanization, these solutions have both benefits and challenges to urban life, depending on their planning objectives and the societal structures. The purpose of the study is to put emphasis on the social inclusion of diverse groups in the context of the smart city projects. This study adopts a qualitative and exploratory research approach to understand the digital divide in smart cities. The data is collected through a literature review based on keyword research on the Scopus database, and it is supported by relevant academic literature to shape the conceptual framework. A thematic analysis was conducted on the digital divide in smart cities to explore the academic debates and gaps in the literature. Accordingly, smart cities have sociotechnical aspects, and their implementations raise questions about social justice concerns by considering the social differentiations within the urban fabrics, rather than depending only on technological implementation processes and business-oriented appraisals. In this sense, this study focuses on the digital divide issues in smart cities by limiting its scope to the social equity discussions.

Keywords: smart cities, digital divide, social equity, sociotechnical perspective

Introduction

Smart cities are envisioned at the intersection of developing technologies and the urban fabric. Over time, the challenges and opportunities of smart cities have become prominent in environmental sustainability and governance discussions, moving beyond the focus on technological adaptation [14]. The concept of smart cities refers to the sociotechnical systems proposed as one of the responses to the rising demands of cities with the aim of enhancing life quality, especially to support intelligent urban development and sustainable socio-economic growth for the citizens [12]. The evolution of cities is mediated by digital infrastructures, and ICTs are embedded into the urban fabric as new modes of urban governance that rely on big data [6]. The term smart city appeared as an urban infrastructure system charged with enabling energy, transportation, housing, and communication provisions while responding to escalating urbanization and population growth, and is synonymously regarded as "digital city" or "intelligent city" [3]. For instance, the "green city" is another concept that overlaps with the notion of smart cities in supporting economic processes and managing environmental resources [5]. Citizens, governments, and private companies are three stakeholders of social infrastructure in the smart cities. Accordingly, human capital appears as one of the crucial components of smart cities, since urban fabric comprises a diverse range of individuals from various socio-demographic backgrounds, and citizens are the end-users of the introduced smart technologies [12].

Social Equity in Smart Cities

The interconnected sociotechnical structure of the smart city design creates challenges for social equity in implementing and developing services to users [9]. Social equity is defined as a key factor for development in smart cities; further related policies are significant in terms of being a bridge between the technological and economic gap in the urban demographic relations. Accordingly, the term digital gap refers to the difference between who can afford technologies and who cannot afford them among citizens [5]. In relation to this, the concept of the "digital divide" pertains to societal differences in access to and knowledge of technology among various social groups. These potential digital gaps within societies can be addressed through adequate digital infrastructure and effective policy implementations in smart city initiatives [1]. Especially concentrating benefits around the smart city implementations, such as advanced infrastructure services and providing sociotechnical solutions in specific areas while excluding others, brings 'digital marginalization' concerns [3].

Furthermore, concerns over reproduction of social inequalities during the transition to a smart society increased with smart cities through 'the smartness-induced inaccess' to services, since the integration of ICT-based smart systems is celebrated in the governmental agenda for optimizing resource allocation and public service provisions [15]. Also, private companies, government bodies, and citizens might dissociate according to their different group interests; further, each smart city projects differ from others in accordance with their unique target groups [9]. In other words, social concerns vary depending on the idiosyncratic social dynamics. It is pointed out that limited dissemination of service, specifically the internet, could bring a "digital divide" while hindering the collective achievement of mass smart information services [12]. To detail, the digital divide has location context to dissociate advantageous and disadvantageous groups depending on the neighborhood-specific accessibility and usability of the digital infrastructures and other services [11]. It is suggested that smart cities contribute to the reproduction of urban inequities. Similarly, the condition of youth in Philadelphia proves that wealthy neighborhoods and their new economy become 'smart' while other parts of the cities are outcasted by digital investments and technology-driven urban change [8].

Mitigating the Digital Divide for the Future of Cities

The deployment of institutionally connected smart technologies in smart cities would bring several problems, not solely the technological challenges, but also the organizational challenges for the policymakers and other related stakeholders [9]. The digital divide is one of the challenges of smart city implementations among developing countries. Concomitantly, every citizen deserves to be equally treated in quality access to ICTs, reaching available telecommunication services and the information and knowledge, regardless of their race, gender, income, and social group positions [5]. It is claimed that the digital divide appears as a significant notion for enacting accessible and inclusive city planning for everyone, and they put emphasis on the digital literacy and digital accessibility of vulnerable groups [12]. Private-public partnerships have prominent role as service providers, in transforming social dynamics of urban places into digitally-inclusive places. Therefore, holistic viewpoint for smart city implementations are suggested to be considered for environmental sustainability, societal wellbeing, and financial sustainability in accordance with the technological integrity [2].

Moreover, Caragliu and Del Bo conduct an empirical analysis on European cities, they analyze whether there is a relation between urban smartness and digital divide, and they state that the enhancing role of smart cities and the digital divide issue, which is not often referred to in the literature on European smart cities

[4]. Their findings demonstrate that medium-upper level smartness has a negative effect on the digital divide, whereas higher level smartness is not associated with inequalities. Therefore, they conclude that ICTs actually have the potential to bring democratic planning if smart technologies are used efficiently in future policy implementations. The concept of digital divide needs to be extended and re-conceptualized from individual level access to public and community-based organizations to fully understand who owns and manages 'big data' in a comprehensive way [10]. Moreover, smart city innovations need to embrace diverse social groups and maintain long-term legitimacy and sustainability planning through social engagements. To highlight, the digital divide emerges in relation to digital society, and it can be mitigated through policy directions since these disparities within society arise and revolve in accordance with the continuous development of new technologies [13].

Methodology

During the paper selection process, a literature review is conducted through keyword research on the Scopus database to gather relevant articles. This study adopts a qualitative and exploratory research approach to understand the digital divide in smart cities. The data is collected through a literature review based on keyword research on the Scopus database, and it is supported by relevant academic literature to shape the conceptual framework. A thematic analysis was conducted on the digital divide in smart cities to explore the academic debates and gaps in the literature. The research question, "In what ways do smart city implementations mitigate the digital divide for social equity?" is defined to guide literature review and keyword selection within the sociotechnical imaginaries framework. Research topics are reduced to social sciences publications in the English language. Articles are selected from query results based on the thematic keywords searches, such as ("smart cit*" AND "digital divide"), by prioritizing their relevance to the study.

Main Results and Discussion

Especially, sociotechnical shifts have been expanding to various spheres of life with different applications around the globe. Herewith, diverse implementations in cities indicate the need for attention on both sociotechnical and environmental aspects of these technological shifts. Since sustainability and life quality have to be holistically considered through navigating the societal consensus in order to attain the effectiveness and efficient design of the smart solutions. Thinking about the smart city implementations brings discussions on improving the life quality of their audiences, whether implementations reach the whole society or partially. Social, in other words, soft infrastructure is an indispensable part of the smart cities, considering the intellectual capital and social capital, these components make smart cities a learning city and a knowledge city for enhancing local knowledge. Otherwise, they overlook the fact that people interpret technological developments in accordance with their backgrounds regarding specific sociocultural, political, and spatial locations. In fact, integration of the various groups regarding both expert and non-expert users into the sociotechnical city life matters for the social equity objectives for everyday life practices. Since a holistic viewpoint not only considers the three main stakeholders, referring to governments, companies, and citizens, but also the various social groups that citizens belong to, based on their different positions in their societies. The digital divide has to be accounted for by referring to its impact on the public life of citizens to participate in urban activities. Smart city initiatives have to implement policies that address the various socio-demographic groups and needs of citizens for an effective and equitable future in accordance with the project objectives.

Conclusion

The objective of this study is to acknowledge human infrastructure within smart city discussions. Smart cities appear as one of the sociotechnical implementations in order to support communities and their development in urban settings. The notion of smart cities brings the social, environmental, and technological dimensions together into the discussion. This paper intends to gather information about the future of smart cities while emphasizing the digital divide in smart cities to recognize various citizen groups and their conditions in being integrated into the new urban systems. Through this approach, smart cities are envisioned with their influence on the societal sphere, while academic literature mainly considers the technological innovations and innovative implementations. In a nutshell, this study aimed to provide a focus on the sociotechnical aspect of smart cities to highlight the significance of social equity for socially inclusive smart urbanism. Since smart city projects rely on the collective dynamics of several stakeholders. Citizen groups are diverse based on their social backgrounds and in-group relations, which are shaped by social, economic, cultural, gender-based, and disability factors. In other words, the group dynamics of citizens should be contemplated within smart city projects, such as socioeconomic status differences in access and digital literacy levels in technology usage. This paper has provided some initial points to the digital divide discussions in smart cities, but wider, in-depth studies are required to examine the topic in academic literature.

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High School Students' Urban Belonging, Cultural Awareness, and Participation Tendencies in Local Government: The Case of İnegöl

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ABSTRACT

Understanding the emotional and social ties that young people establish with the city they live in, their level of knowledge about cultural values and their attitudes towards local decision-making processes are important for the creation of participatory and inclusive urban policies. Addressing the perceptions of young individuals towards the city from a multidimensional perspective is necessary for local governments to develop youth-centred strategies. Developing a sense of belonging to the city where young individuals live, recognising and valuing the historical and cultural heritage of that city, and the desire to be actively involved in urban decision-making processes can be shown among the multidimensional components mentioned. This study aims to examine the interactions of young people living in İnegöl with the city within the framework of urban belonging, cultural awareness and participation tendencies in local government. The three concepts focussed on in the research, on the one hand, strengthen the identity ties that the individual establishes with the city, on the other hand, contribute to the formation of a more democratic, participatory and conscious society structure. In the research, the survey technique was used as a quantitative data collection method and the attitudes of high school students towards these three basic concepts were analysed. The findings reveal that young people's urban belonging is in a significant relationship with cultural awareness, while their desire to participate in local government is strengthened by the sense of belonging. In this context, the study offers suggestions for local governments to involve young people more in the process and contributes to understanding the relationship of youth with the city in İnegöl. The research draws attention to the role of young citizens in the perspective of future city management.

Key words: Urban Belonging, Cultural Awareness, Participation in Local Governance, İnegöl

Introduction

This research aims to analyse the forms of relationship that high school students studying in İnegöl district establish with the city. The research is structured to understand young individuals' urban belonging, cultural awareness levels and their tendency to participate in local government. The main objectives of the study are to examine the emotional and social attachment of high school students to the city they live in, their knowledge and participation levels regarding the cultural structure of the city, and their desire and attitudes towards having a say in the city administration. The importance of the study stems from the fact that young people are seen not only as future citizens, but also as active individuals who have the potential to shape today's urban life. In particular, revealing the perceptions of high school age individuals about the city and their desire to participate in local governance will contribute to the youth-oriented shaping of urban policies. In addition, this research is also noteworthy in terms of local governments and education policies in terms of providing unique data on the youth profile in İnegöl.

The theoretical basis of the research is based on three basic concepts: urban belonging, cultural awareness and participation in local government. Urban belonging refers to the emotional bond, level of social integration and tendency to take responsibility towards the city where individuals live (Tuan, 1977; Pretty, Chipuer & Bramston, 2003) and includes the individual's sense of ownership towards the city and integration with its spatial and social environment. The formation of urban belonging, especially in young individuals, is directly related to variables such as the level of social interaction, satisfaction with urban life and access to urban services (Scannell & Gifford, 2010). Urban belonging also has an important role in the construction of sustainable urban life and social integration (Manzo & Perkins, 2006).

Cultural awareness encompasses individuals' level of knowledge about the historical and cultural values, traditions, symbols, festivals and social heritage of the city they live in and the sensitivity they develop towards these values (Banks, 2001). Cultural awareness strengthens the historical and symbolic aspect of the bond that young individuals establish with the city. Information about local history and culture in educational institutions, opportunities to participate in cultural activities and contacts with the society are effective in the development of this awareness (Ünlü & Yıldız, 2016). Individuals with developed cultural awareness can become more sensitive, more participatory and more embracing individuals towards the identity of the city they live in (Dimitriadis & Kamberelis, 2006).

Participation in local governance encompasses the desire and actions of individuals to participate directly or indirectly in the decision-making processes of the city they live in (Michels, 2011). Youth participation in local government is not only a governance issue, but also an issue that needs to be addressed in terms of democratic citizenship education (Checkoway, 2011). In particular, taking the views of high school students on decision-making processes increases their sense of belonging to the city and contributes to the internalisation of democratic values (Sherrod, Flanagan & Youniss, 2002). Participation can be achieved not only through representative means such as elections, but also through volunteering, youth assemblies, community activities and feedback mechanisms.

Urban Belonging

Urban identity is a multidimensional concept that refers to the emotional, social and cultural attachment that individuals develop towards the city they live in. This sense of belonging encompasses not only physical presence in a space but also the individual's ability to feel at home there, to be part of the social structure, and to be recognised and accepted by that structure (Antonsich, 2010). Therefore, urban identity refers to a process in which an individual's spatial identity is reinforced, social bonds are strengthened, cultural harmony is achieved, and the individual establishes a place for themselves in that city.

In the literature, urban belonging is often intertwined with the concepts of identity, social participation, spatial attachment, and identification with place. Tuan (1977) developed the concept of 'sense of place,' emphasising that the emotional bond an individual forms with the space they inhabit becomes part of their identity. This approach reveals that urban belonging is not only linked to the physical environment but also to the socio-cultural dynamics within that environment. Relph (1976) argued that belonging is formed through a connection with the unique character of a place, noting that the anonymisation or homogenisation of a place can weaken this feeling.

For individuals, urban identity is not only a psychological closeness or identification, but also relates to social participation and responsibility. In this context, it has been observed that individuals with urban identity are sensitive to the problems of the city they live in, tend to participate in decision-making processes, and take responsibility for the future of the city (Lewicka, 2011). Therefore, urban identity is directly related to issues such as participation in local governance, civic consciousness, and urban sustainability (Manzo & Perkins, 2006).

Numerous factors influence the development of urban identity, including an individual's demographic characteristics, life experiences related to the city, level of socio-cultural interaction, and access to urban space (Pretty et al., 2003). For young people in particular, urban identity is directly linked to the process of identity formation. Young people's integration into the city, the level of social inclusion, and cultural representation can either strengthen or weaken their sense of belonging (Wright, 2015). Therefore, examining urban belonging through young people is of critical importance in terms of both individual development and urbanisation policies.

Urban identity is a reflection of the multi-layered relationships that individuals establish with their city. This relationship is a complex process that ranges from spatial attachment to identity construction, social participation to cultural integration. In modern urbanisation processes, an individual's sense of belonging to a city is shaped not only by physical infrastructure but also by factors such as social justice, cultural diversity, participatory governance and inclusiveness. In this context, increasing urban belonging should be one of the fundamental policy objectives of local governments, and young people should be actively involved in this process.

Cultural Awareness

Cultural awareness refers to a conscious attitude that begins with individuals recognising and questioning their own cultural identities, values, beliefs, norms and behavioural patterns, and extends to understanding and appreciating the similarities between individuals from different cultural contexts (Bennett, 1993; Deardorff, 2006). This process involves more than just superficially accepting differences; it encompasses the development of deep empathy and understanding across cultures.

Cultural awareness emerges as a result of individuals gaining knowledge and sensitivity regarding ethnic, linguistic, religious, social, and traditional diversity. Individuals' deep understanding of their own cultures enables them to become aware of their prejudices, stereotypes, and ethnocentric attitudes (Gudykunst & Kim, 2003). While ethnocentrism is defined as the tendency to view one's own culture as superior, cultural awareness, on the contrary, makes it possible to accept cultural relativity and evaluate different cultures within their own contexts. Thus, individuals come to understand that different cultural norms and values are shaped not by a universal standard but by their own social and historical conditions (Triandis, 1994).

Cultural awareness is seen as a fundamental component in communication and interaction processes between individuals from different cultures, especially in today's rapidly globalising world (Spitzberg & Changnon, 2009). In business, education, healthcare and social services, individuals with high cultural awareness are more successful in overcoming cultural barriers and managing multicultural environments. This enables cultural diversity to be seen not as a problem but as a source of richness and opportunity (Banks, 2008).

In academic literature, cultural awareness is defined as a fundamental component of the broader concept of cultural competence or intercultural sensitivity (Deardorff, 2006). Cultural awareness involves not only having knowledge but also the ability to adapt one's attitudes and behaviours by putting this knowledge into practice. From this perspective, cultural awareness is a multifaceted process that encompasses cognitive (knowledge), emotional (attitude) and behavioural (skill) dimensions (Hammer, Bennett & Wiseman, 2003).

On the other hand, the development of cultural awareness is a process that goes through different stages.

According to Bennett's (1993) Cross-Cultural Sensitivity Model, individuals may initially be insensitive to cultural differences (ethnocentrism stages), but through education and experience, they gain cross-cultural sensitivity and begin to respect different cultures and understand their perspectives (ethnorelativism stages). In this process, cultural awareness reduces communication failures and prevents intercultural conflicts (Bennett, 1993).

The importance of cultural awareness is increasing not only at the individual level, but also at the social and institutional levels. Cultural awareness plays a vital role in the development of harmony, social integration, and egalitarian policies in multicultural societies (Banks, 2008). In addition, educational institutions and the business world aim to create inclusive environments by increasing cultural awareness. This leads to increased mutual respect, tolerance, and cooperation among individuals with different cultural backgrounds (Sue, 2001). Cultural awareness is a critical skill that enables individuals to understand themselves and others more deeply and to communicate successfully across cultures. Cultural awareness is based on the acceptance and respect of different cultural realities and is indispensable for social harmony, peace and sustainable coexistence in a globalising world.

Participation in local government is a multidimensional and democratic concept that refers to citizens actively engaging in the governance processes of their geographical region (Arnstein, 1969; Fung, 2006). This participation is not limited to voting; it encompasses the public's direct or indirect contribution to decision-making processes, policy development, planning, monitoring, and implementation (Yılmaz & Telsaç, 2021). Thus, participation in local governance contributes significantly to enhancing democratic quality by ensuring that governance mechanisms are transparent, accountable, and inclusive (Cornwall, 2008).

In the context of democratic theory, local participation is considered one of the fundamental tools for strengthening citizens' relations with the state (Pateman, 1970). Local governments are the closest administrative units where public services that directly affect citizens' daily lives are provided and public decisions are made, making them the level where participation is most intense and effective (Denters & Rose, 2005). Therefore, participation in local governments not only ensures that individuals' voices are heard, but also increases social solidarity and enables local needs to be accurately identified and met (Putnam, 1993).

The forms and levels of participation may vary. Arnstein's (1969) ladder of participation model provides an important framework for understanding the nature of participation by examining citizen participation in eight stages, from manipulation to full citizen control. Accordingly, participation processes are evaluated on a spectrum ranging from passive information sharing to collaboration, joint decision-making, and ultimately social empowerment. Today, this model is widely used to analyse participation in local government.

Participation in local governance occurs not only through official mechanisms but also through various channels such as community-based initiatives, civil society organisations, neighbourhood councils, digital platforms, and public forums (Fung, 2006). With the development of digital technologies, e-participation applications are creating new opportunities for broader and more effective public participation in local governance processes (Chadwick, 2009). However, for this participation to be effective, fundamental principles such as transparency, accountability, and fair representation must be adopted in governance structures (Kooiman, 2003).

The benefits of local government participation include the shaping of public policies in line with local realities, improved service quality, strengthened trust within the community, and reinforced democratic legitimacy (Fung & Wright, 2003). At the same time, participatory processes enable the development of innovative solutions to local problems and the more effective use of social resources (Mansuri & Rao, 2013). However, there are various obstacles to participation in local governance. These include citizens' lack of information, inadequate political culture, resistance to participation on the part of administrators, socio-economic inequalities, and the bureaucratic structures of local governments (Lowndes, Pratchett & Stoker, 2001). Education programmes, capacity-building initiatives, and policies that encourage participation are important for overcoming these barriers (Gaventa, 2004).

Participation in local government is a complex and multidimensional concept that is of vital importance in terms of strengthening democratic governance and supporting local development. Effective participation of citizens in local government processes contributes positively to the social, economic and political development of communities and raises the levels of transparency, accountability and legitimacy in local governance.

Methodology

The aim of this study is to examine the interactions of high school students continuing their education in İnegöl with the city in terms of city belonging, cultural awareness, and tendencies to participate in local government. A quantitative method was used in the research. A structured online survey, with questions prepared by the researcher, was used as the data collection tool. Students attending high school in İnegöl were selected as the sample, and data were collected through online platforms. The data obtained were analysed using descriptive statistics. The study fills an important gap in understanding young people's connections to the city and their tendencies toward participation in local governance. In this context, the aim is to contribute to the development of more effective policies by identifying the needs and expectations of young people for local governments and educational institutions.

Main Results and Discussion

In this study, the perceptions and attitudes of young people studying high school in İnegöl district regarding these three basic concepts were analysed through the data collected by the questionnaire method developed by the researcher. In the study, the convenience sampling method was adopted and data were collected by using the face-to-face survey method with 429 students between January and May 2025. The results obtained are given in Table 1

Item	Yes	No
I generally participate in social and cultural events held in İnegöl.	%25,4	%74,6
I follow current developments related to İnegöl.	%74,3	%25,7
I participate in activities organized by associations, foundations, or any other organizations in İnegöl.	%13,9	%86,1
I follow local festivals and events in İnegöl.	%38,1	%61,9
I have a good knowledge of İnegöl's history and geographical features.	%42,6	%57,4
I have seen most of İnegöl's important buildings and historical artifacts.	%82,4	%17,6
I can name most of İnegöl's symbols.	%88,1	%11,9

I would like to participate in various youth groups formed for İnegöl's future.	%87,6	%12,4
I think young people should be represented in local government.	%78,2	%21,8
I believe that the participation of young people in local governments positively affects decision-making processes.	%82,5	%17,5

The research findings provide important data on the interaction of young people living in İnegöl with the city. Only 25.4% of participants stated that they generally participate in social and cultural events organised in İnegöl, while 74.6% stated that they do not participate in such events. This situation shows that young people are not sufficiently integrated into the social life of the city and that they are reluctant to participate in events. However, in contrast, 74.3% of participants stated that they follow current developments related to İnegöl, which shows that young people are interested in obtaining information about the city they live in. Participation in activities organised by civil society organisations such as associations and foundations or other organisations is quite low. Only 13.9% of young people stated that they participate in such activities, while 86.1% stated that they do not. A similar situation was observed in participation in local festivals and events, with 38.1% of participants stating that they follow such organisations and 61.9% stating that they do not. These data suggest that young people's ties to social life are weak, but that their ties to the city in terms of knowledge may be stronger.

In terms of cultural awareness, 42.6% of participants stated that they had good knowledge of the historical and geographical features of İnegöl, while 57.4% stated that they did not have sufficient knowledge in this regard. On the other hand, a large proportion of young people (82.4%) stated that they had seen İnegöl's important buildings and historical monuments, and 88.1% stated that they recognised most of İnegöl's symbols. These results reveal that young people are in visual or physical contact with the city's cultural heritage, but that this contact is not sufficiently reflected in their level of knowledge. In terms of participation in local government,

87.6% of young people stated that they would like to be part of youth groups formed for the future of İnegöl, and 78.2% argued that young people should be represented in local government. In addition, 82.5% stated that they believe the participation of young people in local government has a positive effect on decision-making processes. These findings clearly show that young people living in İnegöl have a high desire to participate in local governance and expect to be represented. Although participation in social life is low, awareness and desire to participate in governance are quite high. These results indicate that local administrators need to develop policies to include young people in decision-making processes.

Conclusion

This study aims to examine the interactions of young people living in İnegöl with the city in terms of their sense of belonging to the city, cultural awareness, and tendencies to participate in local government. Data was collected through a survey administered to high school students continuing their education in İnegöl. The survey questions were developed by the researcher, and an online survey method was chosen as the data collection tool. The findings provide important insights into young people's relationships with the city. The vast majority of participants (74.3%) stated that they follow current developments in İnegöl. This indicates that young people have a current awareness of the city they live in. Similarly, it was observed that they have a high level of knowledge about the historical structures and important symbols of İnegöl (82.4% and 88.1%). These results reveal that the connection established with city culture and symbolic values is strong among young individuals. However, only 25.4% of participants stated that they regularly participate in social and cultural activities, while 13.9% stated that they participate in association or foundation activities. These rates show that young people have limited participation in becoming active subjects of urban life. This situation indicates that young people's interest in the city remains at a passive level and that active participation mechanisms need to be further encouraged.

The findings regarding participation in local government are particularly noteworthy. 78.2% of participants believe that young people should be represented in local government, while 82.5% believe that young people's participation in local decision-making processes has a positive impact on these processes. These data indicate that there is a strong demand for representation and a desire for democratic participation among young people. Based on these findings, the following recommendations can be made:

- The active participation of young people should be encouraged. Low participation rates in social, cultural and civic activities indicate a lack of interesting and participatory programmes for young people. Municipalities and civil society organisations should plan activities that appeal to young people.
- Young people should be included in local government through youth councils, advisory boards and similar structures. Such structures will not only provide representation but also experience in participation and responsibility.
- Educational activities on city identity should be organised; young people's knowledge of İnegöl's historical, cultural and geographical values should be supported. In this way, the emotional dimension of city identity can be strengthened.
- Local democracy and citizenship-based education programmes implemented in schools will contribute to developing young people's connection to the city and their democratic awareness.
- Volunteer-based projects, cultural heritage programmes and youth-focused digital platforms can be created to increase young people's social capital.

Although young people in İnegöl are cognitively aware of their city, this awareness has not yet translated into sufficient behavioural participation. Young people's strong expectations and desire for representation in local government indicate that urban policies need to be redesigned to strengthen their youth dimension. In this regard, the measures to be taken will both strengthen young people's sense of belonging to the city and contribute to the development of a more democratic and inclusive approach to local government.

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Integrating Green Infrastructure into Smart Cities: The Case of Freiburg

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ABSTRACT

This study examines how green infrastructure can be integrated into smart cities by using the content analysis method, using the German city of Freiburg as a case study. Green infrastructure refers to a network that provides the "components" to solve urban and climatic challenges by building together with nature. Therefore, it is one of the most promising solutions to build a sustainable city and moreover, it creates a strong synergy with smart cities. Given that smart cities are not only the technology-focused cities, but also aim to provide a more sustainable, more livable and more inclusive life for people. Considering that we aim to achieve a sustainable and livable life, green infrastructure is an effective approach to achieving these goals. This study explains the most suitable ways for integrating green infrastructure systems into smart cities. Freiburg is one of the unique cities which demonstrates both smart city and green infrastructure characteristics and furthermore, it is an excellent example of integrating green infrastructure into smart cities, in the light of the fact that it places emphasis on sustainability in transportation, the protection of green areas, the use of renewable energy and the emphasis placed on water management. All of those qualifications make Freiburg one of the best options to use in this study. For this reason, the application of the green infrastructure technologies in harmony with green city systems in Freiburg is being investigated in this study.

Keywords: Green infrastructure, Smart Cities, Freiburg, Renewable Energy, Water Management.

Introduction

In today's world, the importance of integrating green infrastructure into smart cities is steadily increasing. Therefore, this study examines ways to facilitate this integration. It investigates how the combination of sustainability and technology can lead to the development of more livable urban areas. It is a significant topic because urbanization and global warming are driving people to seek sustainable, ecofriendly alternatives, which are often difficult to find due to the lack of attention or importance people give to these issues.

Before proceeding further, it is necessary to clarify the definitions of "smart city" and "green infrastructure" in order to better understand this integration and its potential. The concept of the term, "green infrastructure", simply refers to "a strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity" (1). As can be understood from this definition, green infrastructure possesses all the qualities necessary for supporting a sustainable lifestyle. Moreover, a smart city is "the use of digital and communication technologies and, in this context, it is aimed at high quality resource management and service delivery" (3).

These two concepts are highly compatible in terms of urban sustainability, and their integration may be key to building better cities. However, in order to achieve this, we shall need to develop a clear understanding of these concepts by referring to a real-world example. Accordingly, this study provides insights into this integration by using the example of Freiburg, one of the smart cities that uses green infrastructure to make the city more sustainable and livable.

Methodology

Using comparative analysis, this study compares traditional urban infrastructure construction methods with methods used to integrate green infrastructure into smart cities in Freiburg.

Main Results and Discussion

Freiburg is the perfect example to use in a study which explore about smart cities and green infrastructure because it's defined as "a shining example of the success of Germany's energiewende" (2). It's known for its renewable energy, alternative mobility, sustainable live conditions, solar power and hydro-power projects. The city has long been active in implementing important factors for sustainability, such as renewable energy, public transport, green space and participatory urban development. Also, Freiburg remains at the forefront of the implementation of green building technologies (2). The table below shows some of the programs in Freiburg and also, their aims and effects.

Table 1. Aims and Effects of Green City Programs in Freiburg

Program	Aim	Effects
Usage of Solar Energy	Achieving 100% renewable energy and carbon neutrality for the city	Freiburg maintains very low carbon emissions, with the majority of its energy production based on renewable sources.
Encouragement of Walking and Cycling Instead of Car Usage	Preventing energy waste and promoting sustainable, alternative urban mobility	Freiburg effectively reduces carbon emissions and prevents air pollution by decreasing dependence on motor vehicles.
Usage of Bio-Energy	Utilizing the city's organic waste as an eco-friendly energy source	This program helps reduce environmental pollution from organic waste while simultaneously increasing energy production for the city.

Usage of Wind Energy	Generating electricity from the kinetic energy of wind	The use of wind power, a renewable source, helps prevent various environmental problems and contributes to a sustainable energy generation.
Usage of Hydro-Energy	Generating electricity from the kinetic energy of water	Like wind energy, hydro-energy is a renewable source that helps mitigate environmental issues associated with conventional energy production.
Green Urban Planning	Preserving large portions of the city as green spaces	This program not only promotes walking and cycling but also makes Freiburg an attractive place for students and environmentally conscious citizens.

This table gives us a lot of information about green city programs in Freiburg. Each program has significant aims and effects for the sustainability in the city. Usage of solar energy in the city aims achieving 100% renewable energy and carbon neutrality for the city and provides benefits like low carbon emission. Encouragement of walking and cycling aims decreasing energy waste and promoting sustainable urban mobility which provides low carbon emission and precaution against air pollution. Usage of bio-energy utilizes the city's wastes as a bio friendly energy source, which benefits city's policies about reducing environmental pollution while producing energy. Usage of wind and hydro-energy generates energy from bio-friendly sources, which mitigates environmental issues. And lastly, green urban planning preserves large portions of the city as green spaces, so people prefer walking and cycling. Also, this program makes Freiburg an attractive place for both students and environmentally conscious people (2).

As can be understood from the table, there are lots of ways to apply green infrastructure in smart cities. All the ways in table are made by using both technology and ecological methods. The first program, "the usage of solar energy" plays a key role in term of renewable energy. It basically stores sunshine and turns it into electric energy to use in city. As a result of the program, carbon emission rate in Freiburg has decreased significantly. It's a major effect not only for Freiburg, and also for the world because every little fall on carbon emission helps to close the hole in the ozone layer and indirectly reduces global warming. Also, the second program "encouragement of walking and cycling instead of car usage" does the same effect and decreases carbon emission. Freiburg offers opportunities such as building walking and cycling paths so that people can choose to walk and cycle instead of driving. As a result of this program, air pollution is also decreasing with motor vehicles. Therefore, Freiburg has the lowest car density of any city in Germany (6).

Next 3 programs are all related to the use of renewable energy. Freiburg procures energy from ecological and sustainable sources instead of resources at risk of depletion. Bio-energy is one of the resources available to help meet our demand for energy. It is a form of renewable energy that is derived from recently living organic materials known as biomass, which can be used to produce transportation fuels, heat, electricity, and products (8). It basically depends on getting energy from bio-waste such as wood-waste, plant-waste, animal-waste (fertilizer) and energy plants. Energy production from these kinds of sustainable resources is one of the main aims of green infrastructure. It reduces environmental pollution. Also, wind energy is a pretty useful alternative. The wind brings enormous kinetic energy with itself. This type of energy can be utilized in many different areas if managed properly by people. Hydro-energy also operates on a similar principle. It uses the kinetic energy of water, often saltwater, to produce the energy needed to meet human demands. It's sustainable because water on Earth is never lost and always comes back by water cycle. Therefore, these 3 resources to gain energy, are pretty sustainable, eco-friendly and inexhaustible. And lastly, green urban planning mainly aims to green up the city as much as possible by planting more plants. It supports forest conservation, encourages planting, and enhances overall green life. (5) The people of Freiburg are made aware about how important it is to protect nature for a more sustainable life. People are learning and getting the habits of recycling, planting etc. from kindergarten onward. They grow up with the concept of plant love. As they become adults, they become individuals with green consciousness. Also, Freiburg not only raises awareness but also provides its people with green spaces to enjoy. There are lots of green places for all age groups. This green urban planning program seems like its works because everybody knows Freiburg for its environmentally friendly and sustainable city planning. Especially in Vauban Neighborhood. Vauban is Germany's sustainable heaven. Located 4 km south of Freiburg, the neighborhood offers a perfect environment for those seeking an ecologically sustainable lifestyle. Construction began in 1994 with an eco-friendly infrastructure, and the first residents moved in 1998. Currently, Vauban has a population of approximately 5,000 and a potential job base of approximately 600. Regarding the practices implemented in Vauban, it's less common to find car owners in Vauban than in other areas, as the primary means of transportation are bicycles and walking (7). Another distinguishing feature is its environmentally friendly design approach. Houses in Vauban are built to be highly energy efficient. Solar panels, rainwater harvesting systems, and high-performance insulation are frequently used (4). This demonstrates why Vauban is considered a sustainable neighborhood.

Conclusion

In conclusion, this study defines the terms "green infrastructure" and "smart cities", examines ways to integrate them and highlights their importance for a more sustainable world. Furthermore, it demonstrates how beneficial this integration could be for a better future. This study observes these benefits in the German city of Freiburg and examines some programs that can be implemented in other cities. Freiburg is a valuable example in this sense with its ecological city infrastructure and environmentally aware population. Cities around the world may consider Freiburg as a model, in the light of the fact that sustainability is a significant part of our lives. As we have no alternative planet to inhabit, we must prioritize the protection of the Earth. Integrating green infrastructure technologies into smart city systems represents a promising step toward ensuring environmental sustainability.

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Resilient Cities and Sustainable Future: Youngsters Discuss Future of the Cities

A Youth-Oriented Approach to Sustainable Development in Görükle: Revitalizing Urban Sustainability Through Student Initiatives

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ABSTRACT

This project investigates the sustainable urban development needs of Görükle, a neighborhood in Nilüfer district of Bursa that has become predominantly student-populated following the establishment and growth of Uludağ University. The study aims to identify pressing local issues—traffic congestion, building resilience to earthquakes, access to potable water, and public safety—and to develop youth-led and municipality-collaborative action plans that enhance environmental, economic, and social sustainability. Using a mixed-methods approach, the research combines field observation, surveys (target n≈500), semi-structured interviews with stakeholders, and participatory workshops with student communities. The expected outputs include policy briefs for local authorities, community workshops, dissemination through social media and academic articles, and concrete proposals for pilot interventions mobilized by student initiatives.

Keywords: Görükle; sustainable urbanization; students; urban resilience; potable water access

Introduction

Sustainability has become a central paradigm for planning urban futures: meeting present-day needs without compromising the ability of future generations to meet their own. Görükle, historically a village that expanded through population movements and later studentification, now hosts a sizable student population due to the proximity of Uludağ University. This demographic shift has generated rapid changes in housing demand, service provision, and land use patterns, producing both opportunities and challenges for urban sustainability. Typical urban problems—such as insufficient green space, waste management shortcomings, water quality concerns, traffic congestion, and safety issues—are compounded by the high turnover and specific daily rhythms of student life. These dynamics motivate the present study that places students at the center of sustainable development strategies.

Study area and context

Görükle is located adjacent to the Uludağ University campus in Nilüfer district. The neighborhood's evolution into a student-dominated settlement followed decades of urban growth. Uludağ University reported an enrollment of approximately 73,037 students in the 2023–2024 academic year, contributing to Görükle's transformation. The presence of students has stimulated local commerce and rental markets, but it has also altered the social composition and created infrastructure pressures. Older residents sometimes feel socio-culturally displaced, while the built environment has adapted to student needs—leading to higher density, reduced green areas, and pressure on water and waste systems. These characteristics make Görükle an informative case study for youth-centered sustainability interventions.

Relevance to sustainable development goals

The project directly relates to multiple United Nations Sustainable Development Goals (SDGs), including:
• SDG 2 (Sustainable food and resilient agricultural systems): supporting local food resilience and green spaces.
• SDG 4 (Education for sustainable development): raising awareness and education among students and the broader community.
• SDG 5 (Gender equality): addressing safety and mobility concerns that disproportionately affect women and girls.
• SDG 6 (Clean water and sanitation): improving access to safe drinking water and water infrastructure.
• SDG 7 (Affordable and clean energy): exploring energy-efficient measures in public spaces and buildings.
• SDG 11 (Sustainable cities and communities): improving housing, waste management, air quality, and public spaces.
• SDG 12 (Responsible consumption and production): encouraging waste reduction, recycling, and sustainable consumption practices.
• SDG 13 (Climate action): integrating resilience and adaptation measures against climate and disaster risks.

Originality and research questions

This research is original in its focus on a micro-urban area that has been understudied in the sustainability literature—Görükle—and in centering youth (university students) as primary agents of change. The research asks:
1. What sustainable living interventions have been implemented in Görükle to date, and how effective have they been?
2. Under urban sustainability criteria, how livable is Görükle for students?
3. What specific measures can improve transport, water quality, building resilience, and safety in Görükle?
4. How can student communities be mobilized to participate in and sustain these interventions?

Objectives

The primary objective is to foster sustainable urban living in Görükle by leveraging student-led initiatives and collaboration with local governments. Specific objectives include:
- Conducting a baseline assessment of current sustainability conditions (physical, social, economic).
- Identifying priority interventions across traffic, seismic resilience, potable water access, and safety.
- Designing policy recommendations and pilot activities to be implemented in collaboration with student organizations and local authorities.
- Increasing community awareness and participation through workshops and outreach campaigns.

Methodology

A mixed-methods design will be used. Quantitative data will be collected via structured surveys targeting students and residents (target N≈500), using Likert-scale items to assess satisfaction levels, perceptions of safety, access to services, and environmental awareness. Survey data will be analyzed with SPSS (descriptive statistics, cross-tabulations, and relevant inferential tests). Qualitative data will be gathered through semi-structured interviews with local officials, youth representatives, and community leaders, as well as through field observations of infrastructure and public space. The approach draws on established mixed-methods literature (Tashakkori & Creswell; Baki & Gökçek) and will integrate findings to produce actionable recommendations.

Sampling and data collection

The study will use a non-probability sampling approach for practical reasons, complemented by snowballing through student networks and local organizations. Gender balance will be sought in sampling. The target sample size is approximately 500 respondents to ensure diverse representation and sufficient statistical power for subgroup analyses. Data collection tools include online (Google Forms) and face-to-face surveys, observation checklists, and audio-recorded interviews (with participant consent).

Main problems and proposed solutions

Traffic

Problem: Rapid population growth and student inflow have caused severe traffic congestion, particularly at the main entrance to Görükle, where short trips can take disproportionately long times during peak hours.

Proposed solutions:
1. Assess and optimize public transport services and schedules in collaboration with municipal authorities to reduce private car use.
2. Promote cycling by improving access to bicycles for students, building dedicated bike lanes, and increasing secure bike parking.
3. Coordinate campus access policies to limit non-essential vehicular entry during peak hours, thereby reducing bottlenecks near the campus entrance.
4. Develop route optimization proposals for minibuses and bus lines and advocate for pilot testing through the municipality.

Earthquake Resilience

Problem: Görükle is located within a first-degree earthquake zone. Many older structures may present risks due to aging construction and soil conditions. There is also a shortage of designated and properly equipped gathering areas for emergency shelter.

Proposed solutions:
1. Create a structural inventory and rapid assessment program with municipal and academic experts to prioritize building strengthening.
2. Review and update local emergency plans in line with recent demographic changes and identify usable gathering/shelter areas according to international standards.
3. Promote community drills and awareness programs that engage students and residents in preparedness activities.

Potable Water

Problem: Although regional water utilities report compliance with standards, residents and students often distrust tap water quality due to issues such as limescale, aged distribution pipes, and occasional taste/odor complaints. As a result, many rely on bottled water or point-of-use purification systems (“sumatik”).

Proposed solutions:
1. Expand and optimize the placement of public purified water dispensers (sumatik network) in high-demand student areas.
2. Improve maintenance, monitoring, and cleaning protocols for public water points and develop a responsive maintenance system with local authorities.
3. Conduct periodic water quality testing and publish transparent results to restore public trust and guide remediation measures.

Safety and Gender Equality

Problem: Night-time safety concerns—insufficient lighting, lack of surveillance, and limited late-night public transport—disproportionately affect female students, reducing access to study spaces and social life.

Proposed solutions:
1. Map poorly lit and high-risk pedestrian routes; propose targeted lighting upgrades and CCTV installation in collaboration with municipal authorities.
2. Advocate for increased evening public transport frequency and the creation of safe shuttle services for students during late hours.
3. Implement community-based safety campaigns, peer escort systems, and training to reduce gender-based harassment and improve reporting mechanisms.

Work Packages and Timeline

WP No.	Work Package Title and Activities	Responsible	Timeframe (months) / Success Criteria
1	Baseline assessment: literature review, field observation, mapping of infrastructure and services	Project Team	Months 1 (15%)
2	Survey design and implementation; data entry and preliminary analysis	Project Team	Months 1-2 (20%)
3	Semi-structured interviews and stakeholder consultations	Project Team & Advisors	Months 3-6 (30%)
4	Workshops, dissemination, and pilot activity design with student groups and local authorities	Project Team	Months 6-8 (35%)

Risk Management

Key Risk	Mitigation / B Plan
Respondents rush through survey or provide invalid responses	Insert attention-check items, data cleaning, and exclude low-quality responses before analysis.
Failure to reach target sample size	Use online dissemination via student networks, snowball sampling, and extend data collection period; incorporate face-to-face collection as needed.
Delays in stakeholder cooperation	Schedule meetings early, have alternative contacts, and prepare asynchronous feedback mechanisms (online questionnaires).

Project Management and Research Facilities

The project team comprises a principal investigator, three researchers, and an academic advisor. Responsibilities are shared across work packages. Key facilities available include institutional computers for data storage and analysis, SPSS 23 for statistical analysis, and the Uludağ University library and databases for literature review. Recording devices for interviews and transportation for fieldwork will be budgeted as project costs.

Figure 1. Görükle: Google Earth Snapshot (2005)

Figure 2. Görükle: Google Earth Snapshot (2025)

Dissemination And Expected Impacts

Findings will be disseminated through local workshops with municipal stakeholders and student communities, social media campaigns, an academic conference presentation, and at least one peer-reviewed article. Expected impacts include increased local awareness, improved policy proposals for municipality adoption, and catalyzing student-led pilot projects that demonstrate replicable sustainability practices.

Conclusion

This comprehensive project integrates student energy with local governance to address pressing sustainability challenges in Görükle. By combining rigorous data collection, stakeholder engagement, and applied pilot proposals, the initiative aims to produce actionable, locally-owned solutions that can be scaled to similar studentified urban neighborhoods. The project emphasizes youth participation as both an instrument and an outcome of sustainable urban development.

Acknowledgements

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Microplastic Contamination in Agricultural Soils: Risks, Pathways, and Sustainability Perspectives

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ABSTRACT

Microplastic (MP) contamination in terrestrial ecosystems—especially in intensively managed agricultural soils—has emerged as a growing environmental and agronomic threat. In this study, microplastic pollution in agricultural soil samples from Sakarya (Türkiye), was investigated and the results were evaluated. Additionally, the key sources of microplastics (MPs) in agricultural soils, including plastic mulches, biocatalysts, composts, and irrigation with treated wastewater, are summarized based on the latest international research findings. MPs have been shown to alter soil structure, reduce microbial and enzymatic diversity, impair root development, and act as vectors for pollutants. Furthermore, they can disrupt carbon and nitrogen cycling, contributing to greenhouse gas emissions. Climate change may exacerbate microplastic (MP) pollution in soils by altering degradation rates, mobilization patterns, and biological interactions, thereby intensifying the ecological risks posed by MPs in terrestrial ecosystems. Addressing gaps in management and research, through harmonized methodologies and sustainable land management strategies, is essential to reduce soil MP pollution and maintain agro-ecosystem resilience in line with global sustainability goals.

Key words: Microplastic, Soil pollution, Agriculture, Sustainability, Environmental risk.

Introduction

The extensive use of plastics in agriculture—such as mulching films, greenhouse covers, sludge amendments, and irrigation systems—has inadvertently contributed to increasing microplastic (MP) loads in terrestrial environments. Although marine MP pollution has been studied more intensively, emerging evidence now highlights agricultural soils as critical “sinks” for MPs. Recent studies report MP concentrations in farmland soils exceeding 40,000 particles/kg, particularly in areas where plastic mulching and sludge are common practices (Medyńska-Juraszek et al., 2023; Cai et al., 2024). This abstract critically reviews recent international studies to understand (i) the primary sources and pathways of soil MPs, (ii) the physicochemical and biological impacts on soil systems, (iii) potential threats to food safety and ecosystem integrity, and (iv) mitigation opportunities aligned with sustainability goals.

Methodology

Soil samples were collected from two different agricultural land areas in Sakarya. The samples, taken from the upper layer of the soil, were transferred into clean glass jars, sealed with foil and lids, and then transported to the laboratory. Prior to analysis, the samples underwent oxidation removal with hydrogen peroxide and density-based separation using ZnCl2 salt. After these treatments, the samples were placed on 0.45 µm filter paper and examined under optical and fluorescent microscopes at 10x magnification. Microplastics (MPs) were classified by shape into film, fiber, and particle types, and their images were recorded.

Main Results

1. Results

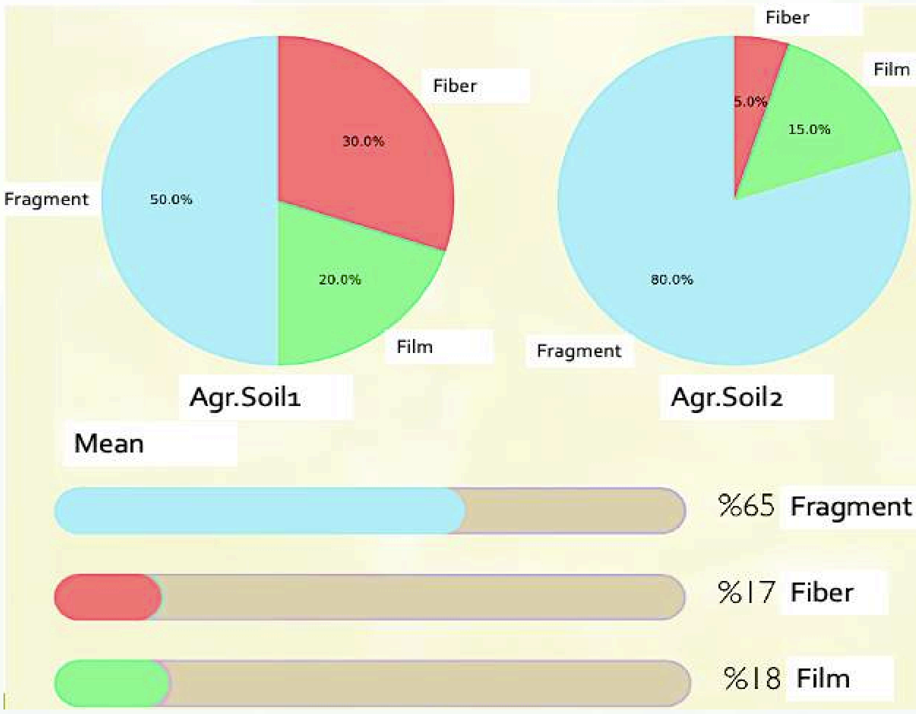

Figure 1. Microplastics in agricultural s oil samples

The microplastics (MPs) found in the analyzed samples were categorized into three groups: fragments, films, and fibers. It was observed that microplastics in the "fragment" form were dominant in all samples. In the Agr.Soil2 sample, fragment-type microplastics were more dominant, while fibers were found to be six times less abundant compared to Agr.Soil1.

2. Sources and Distribution

Primary sources of MPs in agricultural soils include plastic mulch films, composts, treated wastewater irrigation, and biosolid applications (Medyńska-Juraszek et al., 2023; Chia et al., 2023). Atmospheric deposition and plastic degradation also contribute to widespread contamination (Wang et al., 2022). Fibers and fragments are the dominant forms, with PE, PP, PVC, and PET being the most commonly identified polymers (Qiu et al., 2022).

3. Impacts on Soil and Crops

MPs alter soil bulk density, aggregate stability, and water retention capacity (Gao et al., 2025; Mbachu et al., 2021). They also influence microbial community structure and suppress enzymatic activities vital for nutrient cycling (Gao et al., 2025; Qiu et al., 2022). Root development is impaired, and oxidative stress responses in plants are frequently reported (Gao et al., 2025).

4. Environmental and Climate Risks

MPs in soil may enhance greenhouse gas emissions via increased soil respiration and disrupted carbon-nitrogen cycles (Chia et al., 2023). MPs also act as vectors for persistent organic pollutants and heavy metals, further aggravating soil pollution (Wang et al., 2022; Chia et al., 2021).

5. Research Gaps and Standardization Needs

Current challenges include the absence of unified extraction and quantification protocols for soil MPs, lack of deep-soil profile monitoring, and underrepresentation of long-term field-scale studies (Wang et al., 2022; Pan et al., 2024).

Table 1. Common polymer types and their primary agricultural sources

Polymer	Typical Agricultural Source	Dominant Form
PE	Mulch films, irrigation systems	Film, Fragment
PP	Fertilizer bags, containers	Fiber, Pellet
PVC	Irrigation pipes, covers	Fragment
PET	Textile fibers, compost additives	Fiber

Conclusion

Soil-based microplastic contamination presents a growing environmental challenge that threatens soil functionality, crop health, and overall ecosystem integrity. In agricultural contexts, the ubiquity of MPs—primarily from mulch films and organic amendments—requires immediate scientific, regulatory, and societal attention. Future efforts should focus on method harmonization, bio-based material development, and integration of MP mitigation into sustainable land management frameworks.

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Solid Waste Management: A Comparison Of Conventional And Technological Methods

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ABSTRACT

The rapid increase in global population, industrialization, and urbanization has significantly intensified the challenges associated with solid waste management (SWM). "Our country is notably rich in terms of organic waste."(1) Inadequate waste handling not only contributes to environmental degradation but also poses severe threats to human health and sustainable development. As cities expand, the need for efficient and environmentally conscious waste management systems becomes increasingly urgent. This paper aims to explore and compare conventional and smart waste management approaches by focusing on their operational structures, effectiveness, and sustainability outcomes. Traditional systems, primarily based on collection and landfilling, are linear and inefficient, often leading to resource loss and ecological damage. In contrast, smart systems integrate technologies such as the Internet of Things (IoT), Geographic Information Systems (GIS), artificial intelligence, and real-time data analytics to optimize waste handling, improve recycling rates, and reduce carbon emissions. Using Istanbul as a case study, this paper analyzes the transition from outdated practices to data-driven solutions, highlighting the economic, environmental, and social benefits of technological integration. A comparative analysis of past and present systems in Istanbul and other major Turkish cities is presented through visual data to demonstrate the growing adoption of smart systems. The study concludes that technological innovation in waste management plays a vital role in achieving urban sustainability and should be widely supported by policy, public awareness, and investment initiatives.

Key words: Waste Management, Smart Systems, Sustainability, Technological Integration

Introduction

With rapid urbanization and the growing global population, effective waste management has become one of the most pressing challenges facing cities today. Improper waste disposal leads to severe environmental pollution, resource depletion, and health risks. As traditional methods, primarily based on landfilling and manual collection, have proven inadequate in addressing the increasing waste generation, there is a pressing need for more sustainable solutions. In this context, the reuse and more rational utilization of resources have become increasingly important. "Solid waste generated as a result of rapid population growth and excessive consumption is now considered a significant resource that must be evaluated rather than discarded." (3)

This study focuses on comparing conventional waste management systems with smart technologies in managing solid waste. Conventional systems, often characterized by inefficient waste collection, lack of separation at source, and limited recycling, contribute to significant environmental degradation. In contrast, smart waste management integrates cutting-edge technologies such as the Internet of Things (IoT), data analytics, geographic information systems (GIS), and artificial intelligence (AI), which optimize waste collection, reduce environmental impact, and enhance resource recovery. “The main concept of smart waste management is to handle all the waste in the city and monitoring all the process.” (10)

This paper examines the transformation from traditional waste management systems to modern, tech-driven solutions. The primary aim of this research is to evaluate the effectiveness of smart waste management in comparison to conventional practices, emphasizing the environmental, economic, and social benefits of adopting smart technologies. This study will contribute to the growing body of knowledge on sustainable urban waste management solutions

Methodology

The research did not utilize fieldwork or surveys; instead, it examined only official documents and academic sources. Qualitative analysis was used instead of quantitative data. In this context, the study offers a comparison based on existing data, but it can be supplemented with future field research and expanded data analysis.
This project is being conducted using a comparative analysis method. Comparative analysis allows for the systematic examination of phenomena across different contexts within the framework of specific categories (Ragin, 2014). The study analyzed traditional and smart waste management methods to identify similarities and differences.

1. Study Universe
This research focuses on solid waste management practices in urban areas of Türkiye. Istanbul was selected as the primary case due to its significant transformation from conventional to smart waste management systems. Additionally, comparisons were made with medium-sized cities such as Eskişehir to investigate regional disparities and assess the scalability and applicability of smart waste management technologies in different urban contexts.

2. Data Sources

The study is based on secondary data obtained from a variety of reliable sources. These include peer-reviewed academic journals, conference proceedings related to waste management and smart city practices, and official reports and statistics from the Istanbul Metropolitan Municipality and the Ministry of Environment, Urbanization and Climate Change of Türkiye. International references, such as the United Nations Environment Programme (UNEP) and the World Bank’s “What a Waste 2.0” report, were also consulted. Furthermore, prior academic research providing case-specific analysis of Istanbul’s waste management processes contributed to the data set.

3. Data Analysis

A qualitative comparative analysis was conducted to evaluate the differences between traditional and smart waste management systems. The key dimensions of comparison included waste collection methods, storage and disposal techniques, recycling processes, data utilization, and citizen engagement. A temporal analysis was carried out by comparing Istanbul’s waste management practices from the 1950s with those implemented after 2020. The findings were illustrated through visual tools such as tables and charts. Technological tools, including Internet of Things (IoT) sensors, Geographic Information Systems (GIS), and mobile applications, were assessed in terms of their environmental, economic, and operational impacts.

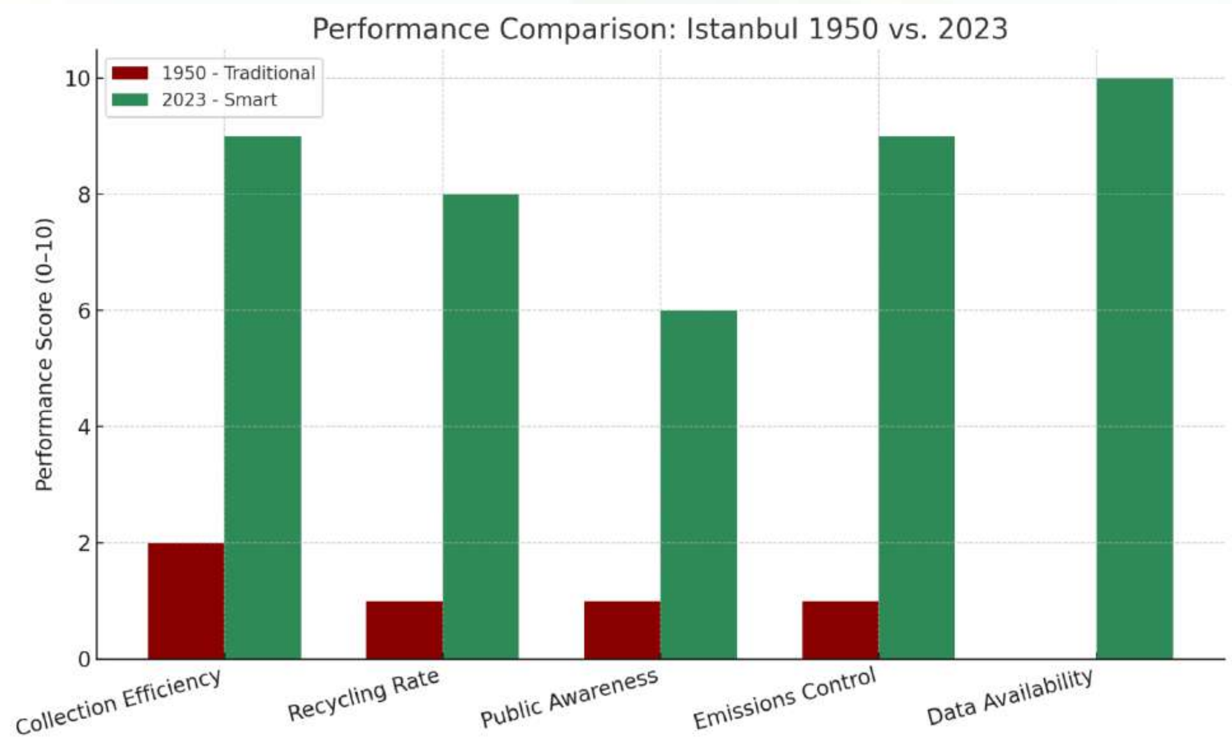
Main Results and Discussion

The comparative analysis of traditional and smart solid waste management systems reveals significant differences in their environmental, social, and economic impacts. These differences become increasingly relevant in the context of rapid urban expansion, growing population density, and the rising urgency of climate change mitigation. Traditional methods, characterized by non-separated waste collection and landfill disposal, have proven to be insufficient for modern urban demands. This inadequacy is particularly evident in densely populated metropolitan areas, where inefficient waste handling exacerbates pollution levels and strains municipal budgets. These practices not only lead to the loss of valuable resources but also cause environmental degradation through soil, air, and water pollution. The accumulation of untreated waste in landfills contributes to greenhouse gas emissions, leachate contamination, and habitat disruption, further highlighting the unsustainable nature of conventional approaches. Furthermore, traditional systems typically lack the infrastructure for recycling and reuse, and they fail to provide accurate data necessary for strategic planning. Without reliable data, municipalities are unable to forecast trends, allocate resources efficiently, or implement evidence-based policies, resulting in reactive rather than proactive waste management.

In contrast, smart waste management systems offer integrated, data-driven solutions by incorporating advanced technologies such as IoT sensors, real-time monitoring, Geographic Information Systems (GIS), artificial intelligence, and mobile applications. These innovative tools enable dynamic interaction between physical infrastructure and digital platforms, creating more adaptive and responsive service delivery models. These systems improve efficiency by optimizing collection routes, reducing fuel consumption, and minimizing operational costs. Through route optimization and predictive analytics, municipalities can significantly cut down on emissions and reduce wear on public service vehicles. The use of sensors to track bin fill levels ensures that collection is performed only when necessary, preventing overflow and reducing labor requirements. This not only conserves energy and labor but also enhances citizen satisfaction and public hygiene in urban spaces. Additionally, data analytics enable municipalities to forecast waste generation trends and develop proactive management strategies. Over time, such capabilities support long-term planning, facilitate circular economy practices, and contribute to sustainable urban development goals, making smart waste management a key pillar in future-ready city planning.

The case study of Istanbul illustrates this transformation clearly. In the 1950s, Istanbul followed a traditional approach: manual waste collection without separation, open dumping, and limited recycling awareness. This resulted in environmental hazards such as methane emissions, poor hygiene, and a lack of public engagement. By 2023, however, the city had adopted a smart system utilizing sensor-equipped bins, energy recovery facilities, and mobile platforms for public education and participation. These advancements have led to significant reductions in pollution and increased recycling rates, showcasing the tangible benefits of smart systems.

The comparison between traditional and smart waste management practices emphasizes that technological integration leads to better resource efficiency, improved public health, and enhanced sustainability. It also highlights the importance of citizen awareness and participation in ensuring the success of modern waste management initiatives. The shift from a linear to a circular model—where waste is treated as a resource rather than discarded—represents a pivotal step toward sustainable urban development.



The comparison of Istanbul's waste management practices between the 1950s and 2023 demonstrates a substantial transformation in operational efficiency, environmental protection, and public engagement. In terms of collection efficiency, the traditional system relied on manual collection at fixed intervals, resulting in waste accumulation on the streets, unpleasant odors, hygiene issues, and pest infestations. In contrast, the modern smart system employs sensor-equipped containers that provide real-time data on fill levels, enabling optimized collection routes and minimizing fuel consumption and emissions. Recycling efforts have similarly advanced; while the earlier system lacked infrastructure and awareness—leading to the loss of valuable materials—the current approach emphasizes source separation, allowing for the recovery of paper, plastic, glass, and organic waste through recycling and composting. Public awareness and participation, once minimal, have been significantly enhanced through the use of mobile applications, which inform citizens about collection schedules and recycling points, thereby promoting environmentally responsible behavior. Emission control has also improved markedly: where waste was once dumped in open areas leading to methane emissions and environmental contamination, today's waste is processed in energy recovery facilities such as incineration and biogas plants, reducing the need for landfilling and contributing to energy generation. Finally, the availability and use of data have seen a pivotal shift; previously absent, reliable data on waste types and quantities is now collected through IoT technologies and analyzed via big data tools, allowing municipalities to forecast trends and design evidence-based waste management strategies. This evolution reflects the broader shift from reactive, linear systems to proactive, circular models rooted in sustainability and technological innovation.

Conclusion

This study reveals that the integration of smart technologies into solid waste management systems plays a crucial role in addressing the growing environmental, social, and operational challenges faced by modern cities. Traditional waste management systems, which primarily rely on manual collection and landfill disposal, have been shown to be inefficient, environmentally harmful, and lacking in adaptability to increasing urban demands. The Istanbul case study illustrates how a transition to smart systems—incorporating technologies such as Internet of Things (IoT) sensors, Geographic Information Systems (GIS), and real-time data analytics—can significantly enhance waste collection processes, reduce emissions, and improve overall efficiency.

Smart waste management systems not only enable better monitoring and optimization of waste-related operations but also foster citizen engagement and data-driven decision-making. These systems support a shift from reactive and linear models of waste handling toward proactive and circular approaches, where waste is viewed as a valuable resource rather than as a disposable burden. The implementation of such systems has been shown to improve public hygiene, reduce greenhouse gas emissions, and increase recycling and energy recovery rates.

The findings of this study emphasize the importance of adopting smart waste management technologies as a fundamental component of sustainable urban development. For cities aiming to meet environmental targets and manage resources effectively, investment in technology, policy support, and increased public awareness are essential. The Istanbul experience underlines how strategic use of technology can lead to measurable improvements in both environmental outcomes and urban quality of life.

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Urban Mobility, Social Inclusion and Sustainable Transportation Strategies: A Fair Accessibility Perspective for Individuals with Autism

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ABSTRACT

This study presents a multidimensional strategic model developed to ensure fair urban accessibility for individuals with autism based on the Sakarya case. Sensory triggers, lack of digital guidance, insufficient staff awareness, and limited representation in policymaking are identified as key barriers. Through interviews with 14 families, 2 NGOs, and 6 experts, and sensory stimulus mapping across 5 transit routes, data were analyzed using content analysis. The proposed model includes four pillars: physical-spatial arrangements, digital support systems, social interaction and education, and participatory governance. The 'Autism-Friendly Urban Transport Ecosystem' proposed for Sakarya aligns with EU social inclusion frameworks such as Horizon Europe and Erasmus+, and offers a replicable model grounded in youth participation and co-design.

Key words: Smart Cities, Autism, Youth Participation, Accessibility, Inclusion

Introduction

Urban mobility challenges for individuals with autism are shaped not only by physical barriers, but also by sensory overload, cognitive confusion, and social exclusion. Smart cities typically offer data-driven, user-centered solutions, but often overlook neurodiversity. This study aims to enhance the independent and dignified urban participation of autistic individuals through a Sakarya-based model.

Main Results

1. Methodology:
- Interviews with 14 families of children with autism
- Focus group sessions with 2 NGOs

- Structured meetings with 6 experts in urban planning, psychology, and transportation
- Sensory mapping along 5 public transport routes
- Thematic coding of data (e.g., sensory stress, navigation difficulty, social isolation)

2. Identified Key Barriers:
- Sensory triggers such as excessive light, noise, and crowding
- Lack of digital wayfinding and journey simulations
- Inadequate staff training and autism awareness
- Lack of representation in policy-making processes

3. Solution Model – Four Components:
a) Physical-Spatial Arrangements: Quiet zones, noise-filtered stops, contrast-based signage
b) Digital Support Systems: ‘Calm Journey’ mobile app, AI-driven recommendations, journey simulation tools
c) Social Interaction & Education: Autism awareness programs, ‘My Travel Buddy’ volunteer accompaniment scheme
d) Participatory Governance: Establishment of ‘Neurodiversity and Youth Access Council’, representation of autistic youth in policy processes

Table 1. Key Barriers and Solution Components

Barrier Type	Developed Solution
Sensory triggers (light, noise)	Quiet zones, sensory filtering, shaded stops, contrast signage
Lack of Digital Navigation	Calm Journey app, mobile navigation tools, simulations
Limited Staff Awareness	Awareness trainings, My Travel Buddy program
Weak Policy Representation	Youth Access Council, enhanced local participation

Figure 1. Autism-Friendly Urban Transport Ecosystem Diagram

Based on the analysis, four major barriers were identified:

1. Sensory triggers in public transport vehicles such as excessive lighting, noise, and social complexity.
2. Lack of customized digital wayfinding systems tailored to the specific needs of autistic individuals.
3. Low awareness of neurodiversity among transportation staff.
4. Inadequate representation of autistic individuals and youth in policymaking.

A strategic solution model was developed to address these barriers, including:

a) Physical-Spatial Arrangements:

- “Quiet zones” reducing sensory load
- High-contrast, minimal, and symbolic signage systems
- Sheltered, noise-filtered waiting areas

b) Digital Support Systems:

- “Calm Journey” mobile app with personalized sensory profiles and recommendation algorithms
- Journey simulations and step-by-step instructional videos
- Route suggestions supported by crowd density data

c) Social Interaction and Education:

- Peer-supported “travel training” programs for youth
- Autism awareness training modules for bus drivers and staff
- “My Travel Companion” mentoring program in collaboration with Sakarya University

d) Participatory Governance:

- Proposed “Neurodiversity and Youth Accessibility Council” in Sakarya
- Inclusion of young autistic individuals in policy development
- Mandatory accessibility impact assessments for new projects

Discussion

This model is not merely a technical solution but a transformative strategy to enhance social inclusion. Compared to literature such as Brazil’s GAIA guide, UK’s HCT Travel Training, and the ATTRI initiative in the USA, the Sakarya model stands out for its local context and emphasis on youth engagement. Empowering youth to create solutions for their peers reinforces not only access but also a sense of belonging.

Global Practices Compared

1. Mobile Transportation Apps – Brazil
The GAIA guide examined apps like Google Maps, Waze, and Moovit, highlighting the inability of autistic

users to customize white spaces, fonts, or colors—leading to increased cognitive load.

2. **Public Transport Studies – UK, New Zealand, USA**
   - *New Zealand (Wellington)*: Used visual scripts for travel preparation, encouraging off-peak travel.
   - *UK (HCT Travel Training)*: Enabled hundreds of young people with autism to travel independently, saving approximately £32 million annually in rural areas.
   - *USA*: Implemented in-vehicle tools to reduce sensory overload—users found predictability and sensory control improved comfort.

3. End-to-End Travel Chain – Global Studies

- **Product Reviews (2023–2024):**
  o Many studies analyze the entire journey chain of an individual with autism—from home to destination—and suggest steps to simplify and support this process.
- *Portugal (Viana do Castelo)*: The "Viana+Acessível" app used route optimization algorithms to support inclusive mobility for all.

4. Autonomous Vehicles – USA

- Prototypes were designed specifically for individuals with autism and caregivers, focusing on safety, comfort, and supervision through human-centered design.

5. Urban Planning – Iran

- In Tehran's District 8, access needs of disadvantaged groups, including individuals with autism, were analyzed, and recommendations such as "complete streets" and park-and-ride systems were proposed.

Strategic Model Proposal for Sakarya:

"Autism-Friendly Urban Mobility Ecosystem"

1. Physical-Spatial Compatibility:

"Quiet Zones & Sensory-Friendly Routes"
Goal: Ensure safe and low-stimulation transit options for autistic individuals with up to 60% improvement in usability.

Proposals:

- "Quiet Hours" in buses/trams
- "Shadow Stops" with noise-dampening materials and soft lighting
- High-contrast, icon-based route signs

2. Digital Support:

"Calm Journey Mobile Platform"

Goal: Improve travel independence by up to 70% through digital planning tools.

Proposals:

- Route customization avoiding crowds and stimuli
- Journey step-by-step simulation videos
- AI-powered personalized travel suggestions

3. Social Inclusion:

"Travel Education & Awareness Workshops"
Goal: Increase autism awareness by 45% through pre-travel training and public sensitization.

Proposals:

- Travel Training programs adapted from the UK
- "My Travel Companion" volunteer initiative with university students
- Mandatory staff training on autism-friendly service

4. Governance and Policy Participation:

"Accessibility Advisory Board"
Goal: Reduce complaints by 30% and ensure equity in urban services.

Proposals:

- Establish a Neurodiversity Commission within Sakarya Municipality
- Participatory board including families, teachers, NGOs, and transport reps
- Mandate accessibility impact evaluations in all new urban projects

Conclusion

Including individuals with autism in urban life is essential for the sustainability of smart cities. This model should be considered not only a technical framework but also a societal transformation strategy. Compared to examples from Brazil, the UK, and the US, the Sakarya model stands out for its local relevance and youth-centered participation. It provides a scalable and inclusive framework where autistic individuals are positioned not only as beneficiaries but also as co-creators.

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A Holistic and Preventive Environmental Management Approach to Evaluating Plastic Recycling Facilities

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ABSTRACT

Plastic recycling facilities play a crucial role in reducing plastic pollution; however, without holistic management, they may present considerable environmental and public health risks. This study analyzes key components such as waste management, emission control, wastewater discharge, and occupational exposure risks within the context of a comprehensive and preventive environmental management approach. The framework emphasizes the importance of proactive risk assessments, pollution prevention strategies, and circular economy integration, underlining critical aspects for transparency, sustainability, and public health protection in the recycling sector.

Key words: Plastic recycling, Environmental management, Pollution prevention, Circular economy, Risk assessment

Introduction

As urbanization accelerates globally, the linear economy model defined as 'take, make, dispose' has expanded unprecedentedly. This expansion has exposed the world to serious risks in resource procurement and increasing waste generation pressures (Zhang et al., 2022). Global solid waste production has risen from less than 0.3 Mt/day in 1900 to over 3.5 Mt/day in 2010, with projections estimating 46 billion tons of total global waste by 2050 (Maalouf et al., 2023). The circular economy, which aims to increase resource efficiency in industrial ecosystems, promotes closed-loop systems based on the principles of reduction, reuse, and recycling (3Rs) to minimize waste generation and convert existing waste into secondary raw materials. Originating from ecological economist Boulding's 1966 'spaceship economy' theory, the circular development model seeks to decouple global economic growth from finite resource consumption, promoting sustainable waste-resource management (Zhang et al., 2022). Plastics, widely used in packaging, textiles, construction, automotive, electronics, medicine, and agriculture, pose severe environmental and ecological challenges when discarded. Due to their persistence and transformation into micro- and nanoplastics that disseminate into water, soil, and air, plastic waste threatens ecosystem health. Globally, less than 10% of plastic waste is recycled, while 79% is directly released into terrestrial and aquatic environments, generating toxic effects particularly on marine and terrestrial organisms and indirectly threatening human health through the food chain. Furthermore, the environmental costs associated with plastic production and disposal, such as energy consumption and greenhouse gas emissions, are substantial and cannot be ignored (Shen et al., 2020). Therefore, sustainable plastic waste management is vital for both environmental protection and public health.

Plastic recycling facilities play a crucial role in mitigating plastic pollution by reprocessing plastic waste into raw materials. These facilities contribute to circular economy objectives by particularly reducing the amount of plastic released into the environment. However, the sustainable realization of these potential benefits necessitates the operation of such facilities within a holistic management framework that fully incorporates environmental and health dimensions. In the absence of effective environmental management systems or when operated in an uncontrolled manner, these facilities may give rise to significant environmental issues, including noise pollution, generation of hazardous waste, and the emission of various pollutants during processing. Moreover, inadequate occupational safety measures and the lack of emission control systems can pose serious health risks to both workers and nearby communities. The literature highlights that personnel working in mechanical and chemical recycling processes may be exposed to phthalates, bisphenol-A (BPA), and other toxic compounds (Hasan et al., 2024).

To minimize the environmental impact of these facilities, it is essential to regularly monitor air, water, and soil quality parameters, conduct life cycle assessments, and ensure that qualified personnel are employed. Ultimately, plastic recycling should not shift from being a solution to becoming a new source of environmental and public health problems; this can only be prevented through strategic planning, effective monitoring, and a multi-stakeholder governance approach.

Waste Management Hierarchy and Plastic Recycling

The waste management hierarchy generally consists of the following sequential steps: prevention, reuse, recycling, energy recovery, and ultimately, disposal (Awino et al., 2024). This hierarchy offers a critical roadmap for reducing the environmental impacts of plastic waste, which tends to persist in nature for extended periods. Source reduction of plastic waste not only supports the transformation of consumption habits but also minimizes waste generation. Reuse and recycling practices extend the lifespan of materials, reduce raw material demand, and significantly lower greenhouse gas emissions. However, the effectiveness of this hierarchy is limited by low recycling rates and the fact that most plastic waste is still directed toward disposal. Therefore, preventive and circular economy-oriented strategies focusing on the upper tiers of the hierarchy are of paramount importance in plastic waste management.

The U.S. Environmental Protection Agency (EPA, 2025) acknowledges that no single waste management approach fits all materials and waste types, and has thus established a Non-Hazardous Waste Management Hierarchy ranked by environmental preference. This hierarchy prioritizes waste prevention, reuse, recycling, and composting, thereby promoting sustainable materials management while aiming to reduce greenhouse gas emissions that contribute to climate change.

Proper classification of non-hazardous waste in solid waste management is essential for reducing environmental impacts and enhancing resource efficiency. Within this context, the Non-Hazardous Materials and Waste Management Hierarchy, developed under the EPA's Sustainable Materials Management framework, emphasizes managing non-hazardous waste based on environmental priorities. Plastics, which are widely found in household, industrial, and commercial waste streams, are generally categorized as non-hazardous. Due to their increasing consumption, long-term environmental persistence, and low recycling rates, plastics should be prioritized particularly in the "source reduction," "reuse," and "recycling" stages of this hierarchy.

Unfortunately, in practice, plastics are still predominantly managed through disposal techniques—such as landfilling or environmentally inappropriate incineration. In recent years, scientific research has increasingly focused on eco-friendly or energy recovery-based technologies for plastic waste, including biodegradation, pyrolysis, chemical recycling, and the use of plastics as alternative fuels (Bénard et al., 2022).

Figure 1. EPA's Non-Hazardous Materials and Waste Management Hierarchy for Sustaiable Materials Management.

Environmental Performance Of Plastic Recycling Facilities

Plastic solid wastes are subject to recycling, enabling their reuse as raw materials or conversion into new plastic products. Before recycled materials can be converted into new products, waste must be processed into secondary raw materials (Ragaert et al., 2017), a phase commonly referred to as End-of-Waste. In mechanical recycling, the process typically involves stages such as grinding, washing, agglutination, extrusion, and quenching (Al-Salem et al., 2009). The initial stages of the mechanical recycling process are particularly critical, as they significantly influence the quality of the final product.

In chemical recycling, techniques such as chemolysis, pyrolysis, fluid catalytic cracking, hydrogenation, and gasification are employed (Ragaert et al., 2017).

Plastic recycling processes generally begin with waste collection and follow a series of steps, which may vary in sequence or frequency depending on facility operations:

1. **Collection and Transfer**: The logistical process of collecting waste from source points and transporting it to recycling, intermediate processing, or disposal facilities.
2. **Sorting and Classification**: Waste is sorted based on characteristics such as shape, density, size, color, or chemical composition.
3. **Baling**: If plastics are not processed on-site, they are usually compacted into bales to facilitate transportation.
4. **Washing**: Organic pollutants and contaminants are removed in this stage.
5. **Grinding**: Plastics are reduced in size to smaller, manageable fragments.

6. **Compounding and Pelletizing**: The materials are transformed into pellets or granules that can be more easily processed by converters depending on the intended application.

The general steps in plastic recycling processes are shown schematized in Figure 2.

Figure 2. Plastic recycling processes (Indpro, 2025).

The plastic recycling process begins with the classification of waste materials based on their polymer types, considering their distinct physical and chemical properties. This separation is carried out either manually or through automated systems such as conveyor belts, infrared sensors, and air classifiers. Once sorted, the plastics are shredded into smaller pieces using granulators or high-speed shredders, thereby enhancing their manageability and suitability for subsequent processing stages. The shredded materials are then washed with hot water and chemical agents to remove contaminants such as adhesives, dirt, and organic residues, followed by drying through centrifugal force or hot air circulation. A secondary sorting phase is subsequently conducted to ensure the homogeneity of color and polymer purity, thereby improving the quality of the final recycled material. The purified plastic fragments are stored in silo systems to protect them from environmental factors like humidity, heat, and dust, and are conveyed pneumatically to the extrusion unit. In the extrusion stage, the plastics are melted and reshaped into continuous strands or filaments, which are then subjected to pelletization to form uniformly sized granules. In the final stage, these pellets are used in injection or blow molding processes to manufacture a variety of new plastic products such as bottles, containers, and bags. This transformation enables plastic waste to regain both economic value by being reintroduced into the production cycle.

The global plastic waste crisis continues to escalate, necessitating the development of sustainable waste management strategies (Geyer et al., 2017). Recycling has emerged as a preferred approach to mitigate plastic pollution and conserve natural resources (Sambyal et al., 2025).

However, recent studies highlight that, in the absence of appropriate management practices, plastic recycling facilities may themselves become sources of environmental contamination (Hopewell et al., 2009; Dong et al., 2024; Merrington et al., 2024). Uncontrolled emissions, contaminated wastewater, and the release of microplastics during mechanical processes have raised significant concerns among regulatory bodies and local communities (Blettler et al., 2017). This study underscores the pollution potential of plastic recycling facilities and proposes an integrated, preventive environmental management perspective to evaluate their environmental performance.

1. Wastewater

In plastic recycling facilities, wastewater is generated from processes such as washing, label and contaminant removal, grinding, hot water baths, and chemical pretreatment. These wastewaters are typically characterized by high levels of organic pollutants, suspended solids (TSS), heavy metals (Vollertsen and Hvitved-Jacobsen, 2000), detergent residues, oil and grease, microplastics (Le Tran et al., 2023), and other contaminants. As such, multi-stage and integrated treatment systems are often necessary for their effective treatment.

The treatment of wastewater from plastic recycling operations generally begins with physical pretreatment units such as screens, grit chambers, and oil separators to remove coarse solids, sediments, and oil-grease. This is followed by chemical coagulation-flocculation and sedimentation processes, which target suspended solids, microplastics, and dissolved pollutants. Recent studies also report the use of advanced treatment technologies—such as sand filtration, Dissolved Air Flotation (DAF), membrane filtration systems (UF, NF, RO), and advanced oxidation processes—implemented in an integrated fashion due to the high pollutant load of these effluents (Chen et al., 2020; Zhang et al., 2021). Particularly in small and medium-sized facilities, compact treatment units involving selected physicochemical processes are commonly used.

It has been reported that modern washing facilities can significantly reduce water consumption to as low as 2–3 m^3 per ton of plastic material (Ozdemir & Yel, 2023). However, to minimize water pollution, the implementation of advanced treatment systems along with wastewater monitoring and reuse strategies is necessary. The following tables present environmental discharge standards applicable to plastic recycling facilities in Türkiye. These standards, as specified in the Turkish Water Pollution Control Regulation (SKKY), define the legal discharge limits for various physical, chemical, and biological parameters applicable to wastewater discharged from solid waste recovery and disposal facilities and other types of industrial operations.

Table 1. SKKY Table 20.6: Sector – Solid Waste Recycling and Disposal Facilities

Parameter	Unit	Composite Sample 2-Hour	Composite Sample 24-Hour
Chemical Oxygen Demand (COD)	(mg/L)	700	500
Total Kjeldahl Nitrogen	(mg/L)	20	15
Total Suspended Solids (TSS)	(mg/L)	200	100
Oil and Grease	(mg/L)	20	10
Total Phosphorus (P)	(mg/L)	2	1
Total Chromium	(mg/L)	2	1
Chromium (Cr^{6+})	(mg/L)	0.5	0.5
Lead (Pb)	(mg/L)	2	1
Total Cyanide (CN^-)	(mg/L)	1	0.5
Cadmium (Cd)	(mg/L)	1	0.5
Iron (Fe)	(mg/L)	10	5
Fluoride (F^-)	(mg/L)	15	10
Copper (Cu)	(mg/L)	5	3
Zinc (Zn)	(mg/L)	5	3
Fish Bioassay (ZSF)	-	2	2
pH	-	6–9	6–9

Table 2. Table 20.5: Sector – Other Industrial Wastewaters (Backwash Waters of Drinking Water Filters and Similar)

Parameter	Unit	Composite Sample 2-Hour	Composite Sample 24-Hour
Chemical Oxygen Demand (COD)	(mg/L)	100	70
Total Suspended Solids (TSS)	(mg/L)	150	100
pH	-	6–9	6–9

Plastic washing processes in recycling facilities generate significant volumes of wastewater (Ozdemir & Yel, 2023). Furthermore, it is understood that millions of plastic debris pass into the water and the environment during the process. In Figure 3 (a) and (b), images of a plastic recycling plant and samples of waste wash water generated in plastic recycling plants are presented

a) Plastic recycling plant (Aerofloataus, Australia, 2023)

b) Waste wash water in plastic recycling plants (Aerofloataus, 2023; Shutterstock, 2025)

c) Richmond, Indiana (ABD) – April 2023 (time, 2023) d) Kartepe, Kocaeli (Türkiye)- July 2023 (AA, 2023) e) Halfar, Malta – July 2025 (sustainableplastics, 2025)

(Examples of intentional or unintentional fires in plastic recycling facilities)

Figure 3. Some example images from plastic recycling facilities, Plastic recycling plant (a), plastic waste wash water in plastic recycling plants (b) and recycling facilities fires (c, d, e).

Mechanical recycling processes such as shredding and grinding can release microplastics into the environment if proper containment measures are not implemented (Kallenbach et al., 2022). Additionally, non-recyclable residues are often sent to landfills or incineration, contributing to secondary pollution. Source separation, advanced sorting technologies, and product design for recyclability are critical to minimizing unrecoverable waste.

As shown in the relevant tables, existing environmental standards and regulations do not include any parameter limits specifically addressing microplastic pollution. Therefore, assessing the microplastic potential and associated risks of wastewater generated from plastic recycling processes is of utmost importance.

2. Air Pollutant Emissions

Recycling operations typically release volatile organic compounds (VOCs), particulate matter, and process-related pollutants. In particular, during mechanical recycling, substantial emissions of microplastics and nanoplastics (MP/NPs) can be dispersed into the air during routine shredding processes. These procedures may expose workers to high airborne concentrations of MP/NPs, especially in the 10 to 100 nm size range (Swinnerton et al., 2024). Furthermore, insufficient ventilation and the absence of closed-loop systems in facilities can exacerbate indoor air quality issues.

In addition, fires occurring at plastic recycling facilities constitute a significant environmental concern. Across various regions of the world, fires have been reported at plastic recycling plants that produced massive smoke plumes visible from kilometers away and persisted for several days. As illustrated in Figure 3 (c, d and e), several examples of large-scale fires are presented, the causes of which—whether intentional or accidental—remain unclear. According to data from American experts, the frequency of such fires is rapidly increasing. In 2022 alone, 390 major fires were reported in the United States and Canada, with actual numbers estimated to be substantially higher. These fires release toxic gases and fine particulates into the atmosphere, which can be transported far beyond the site of origin via air currents, contributing to air, water, and soil pollution on a regional and even global scale. This clearly demonstrates that the environmental impacts of plastic recycling facility fires transcend geographic boundaries.

3. Occupational and Public Health Risks

Workers in recycling facilities are exposed to chemical fumes, excessive noise, and physical hazards. Prolonged exposure to such environments may lead to respiratory problems, skin disorders, and ergonomic injuries. Surrounding communities may also be at risk due to fugitive emissions and the lack of adequate buffer zones. A preventive management plan incorporating occupational health surveillance and community engagement is essential.

4. Policy Integration and Circular Economy Framework

Implementing regulatory standards such as Best Available Techniques (BAT), Environmental Impact Assessment (EIA), and ISO 14001 can support environmental compliance. Integrating recycling operations within circular economy frameworks ensures resource efficiency and environmental equity. Eco-design, extended producer responsibility, and real-time environmental monitoring must be institutionalized.

Conclusion and Discussion

While plastic recycling facilities play a critical role in advancing circular economy goals, current practices often fall short of adopting a holistic and preventive environmental risk management approach. Recent studies have revealed that most facilities operate reactively, responding only after incidents occur, rather than employing proactive pollution prevention and sustainable production strategies (Awino et al., 2024; UNEP, 2023; OECD, 2022). This reactive stance has been linked to persistent environmental impacts, including greenhouse gas emissions, wastewater pollution, microplastic release, and airborne dust (Yadav & Samadder, 2023; Munir et al., 2022). Although the European Union and some developed countries have begun incorporating proactive tools such as Life Cycle Assessment (LCA), resource efficiency metrics, and Material Flow Analysis (MFA) into plastic recycling, the implementation of these tools remains limited in many developing nations (Jiang et al., 2023; Velázquez-Martínez et al., 2022). Moreover, the absence of active risk assessment systems increases the frequency of environmental incidents such as workplace accidents, fires, and VOC (volatile organic compound) emissions (Zhang et al., 2023).

The lack of preventive strategies also hinders progress toward circular economy goals. Performance indicators such as recycling efficiency, output quality, and carbon footprint are directly influenced by the presence or absence of such strategies (Wang et al., 2022). Therefore, achieving environmental sustainability in plastic recycling facilities requires the integration of proactive, monitoring-based, and preventive management systems into operational decision-making processes.

Comprehensive assessments of plastic recycling facilities from a preventive environmental management perspective have identified several critical environmental and operational deficiencies. In most facilities, environmental impacts on air, water, and soil components are not systematically monitored, and environmental impact assessments are either limited or absent (Hopewell et al., 2009; Awino et al., 2024). Rather than implementing pollution prevention strategies, many operators rely on reactive, post-incident responses (UNEP, 2023). The lack of proper sorting of incoming plastic waste reduces recycling efficiency and degrades material quality (Brouwer et al., 2018). Furthermore, even where environmental management systems such as ISO 14001 are in place, they often fail to incorporate life cycle thinking or align with circular economy principles (Yadav & Samadder, 2023). Finally, the absence of regular and comprehensive training for staff on environmental awareness, occupational safety, and process improvement is a major constraint to achieving sustainability (OECD, 2022).

Plastic recycling must evolve from being a reactive waste diversion tool into a proactive environmental management model. A systems approach that incorporates pollution prevention, health and safety, regulatory compliance, and community engagement is essential. Aligning recycling operations with sustainability goals and circular economy principles can yield long-term environmental and societal benefits. Unfortunately, noncompliance with the waste management hierarchy and circular economy principles leads to excessive production, incineration, landfilling, and open dumping.

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Child Friendly Public Spaces: An Evaluation on Istanbul Pendik Orhangazi Neighborhood

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ABSTRACT

This study comprehensively examines children's experiences of public spaces in the Orhangazi neighborhood of Pendik, Istanbul, within the framework of the concept of a "child-friendly city." A child-friendly city refers to living spaces where children have access to safe, accessible, and play-friendly environments (UNICEF, 2004). The theoretical framework of the study is based on Lefebvre's concept of "the right to the city" (Lefebvre, 1996), Hart's "Participation Ladder" model (Hart, 1992), Jacobs' "eyes of the street" approach (Jacobs, 1961), and Ward's "child in the city" perspective (Ward, 1978). These approaches focus on the relationships children establish with the city in terms of spatial justice, belonging, and visibility.

Data obtained through semi-structured interviews, spatial observations, and participatory drawings revealed that children encounter qualitative problems rather than physical barriers in accessing public spaces. Security concerns, lack of functional diversity in spaces, and poor design quality significantly limit children's opportunities to use public spaces. Children mostly feel a greater sense of belonging in the informal spaces they create themselves and move more freely in these spaces. The findings also show that children's visibility and participation levels in the city are generally low and that participatory processes are inadequate. It was emphasized that existing public spaces have significant shortcomings in meeting children's physical, social, and emotional needs.

In conclusion, the study recommends that local governments more effectively involve children in decision-making processes; prioritize functional diversity and sustainability in design; enhance social safety in public spaces; and raise awareness of children's rights through interdisciplinary collaboration.

Key words: Child-Friendly Cities, Public Space, Spatial Justice, Accessibility, Urban Safety

Introduction

Today's cities are environments where spatial, social, and economic dynamics are becoming increasingly complex. Within this complexity, creating accessible, fair, and inclusive environments for all city users is becoming increasingly important. In this context, the place and experience of children, who are among the most vulnerable yet dynamic actors in urban life, opens up a critical area for discussions on spatial justice and social equality.

This study examines the extent to which cities are livable and accessible for children within the framework of the concept of "child-friendly cities." As defined by UNICEF, a child-friendly city is one where children can grow up healthy, move around safely, play, express themselves, and participate in decision-making processes (UNICEF, 2004). This approach envisions children not merely as a group that needs protection but as active participants in urban life.

Within the scope of the child-friendly city concept, this study focuses on three fundamental concepts: spatial justice, belonging, and visibility. Spatial justice refers to the equal access of all groups in the city—particularly those in disadvantaged positions—to services, open spaces, and resources (Soja, 2010; Harvey, 2008). A sense of belonging refers to the strength of the psychosocial bonds children form with the spaces they inhabit, while visibility describes the ways in which children sustain their presence as active participants in urban life. The theoretical foundation of this study is Henri Lefebvre's concept of "the right to the city." According to Lefebvre, the right to the city encompasses not only the right to live in the city but also the right to shape and transform it (Lefebvre, 1996). This perspective highlights that children should be active agents rather than passive objects in the shaping of urban spaces. Roger Hart's "Ladder of Participation" model was used to examine the extent to which children can be involved in this process (Hart, 1992). This model allows for the assessment of the extent and manner in which children participate in decision-making processes.

On the other hand, Jane Jacobs' concept of "the eyes of the street" emphasizes that the most important factor in ensuring the safety of public spaces is the constant presence and interaction of their users (Jacobs, 1961). This approach shows that children's visibility and activity in public spaces play a critical role not only in terms of the liveliness of the space but also in terms of social integration. Colin Ward's "child in the city" approach, on the other hand, considers children's relationship with urban spaces not only as physical use but also as a process of experience, creativity, and reproduction (Ward, 1978). This perspective makes it possible to evaluate children as actors who not only use the city but also reinterpret and transform it.

Public spaces are more than just physical spaces; they are social spaces where social interaction, everyday life practices, a sense of community, and belonging are produced. However, even though children are among the most active users of these spaces, they often remain "invisible users" in urban planning and design processes. This invisibility can lead to children's needs and expectations not being reflected in spatial policies, thereby exacerbating issues such as social exclusion, segregation, and inequality. Child-friendly public spaces should not only provide safe physical environments but also be designed as spaces where children can play, form social relationships, participate, and express themselves (UNICEF, 2004).

In the context of Turkey, rapid urbanization, unplanned construction, and dense building stock, especially in large cities, seriously limit children's access to quality open spaces. In this context, Orhangazi Neighborhood in the Pendik district of Istanbul provides a noteworthy example of a child-friendly city approach. The neighborhood has been affected by urban transformation processes and has a structure characterized by high social diversity and the coexistence of different socioeconomic profiles. Therefore, children's experiences of public spaces in this neighborhood should be examined not only in terms of the quality of the physical environment but also in terms of spatial justice, social inclusion, and local governance.

This study aims to examine children's access to public spaces and their relationship with these spaces in a multidimensional manner, specifically in Orhangazi Neighborhood. It focuses on the question of how children can be made more visible and participatory in urban life through a rights-based approach.

Methodology

This study was designed based on qualitative research methods and conducted in Orhangazi Neighborhood in Pendik district of Istanbul. The research aimed to understand children's practices in using public spaces, their access to these spaces, and the relationships they establish with them. It also focused on how fundamental concepts such as spatial justice, social inclusion, and visibility are reflected at the local level.

Research Methodology and Data Collection Process

Three main methods were used in the data collection process:

1. Semi-structured interviews: A total of 55 interviews were conducted with children aged 7–16 living in the neighborhood. The interviews explored how and how often children used public spaces, which areas they preferred, whether they felt safe, and the relationships they established with these areas.
2. Spatial observation and mapping: Open and public spaces in the neighborhood were observed; the times and ways in which children used these spaces and the behavioral patterns that emerged during these uses were recorded. In addition, children's daily routes and access to play areas were mapped and analyzed.

Data Analysis Method

The collected data were evaluated using descriptive analysis methods. Interview recordings were coded thematically; during the analysis process, evaluations were made based on fundamental concepts such as "accessibility," "safety," "participation," "belonging," and "right to play." Spatial observation findings were processed on neighborhood maps; drawing studies were interpreted qualitatively in the context of children's perceptions.

Main Results

In this section, the relationships that children living in Orhangazi Neighborhood have with public spaces are evaluated under five main themes based on interviews and one-on-one observations: accessibility, safety, functional diversity, belonging, and design quality.

1) Accessibility

The majority of children interviewed for the study stated that they did not encounter physical barriers when accessing open spaces where they play, but noted that these spaces were insufficient in number and not located close to each other in the neighborhood. In particular, some children stated that they preferred vacant lots where cars do not pass because there are no safe places to play near their homes. This situation shows that children's daily mobility areas are shaped in an unplanned manner.

The mapping study also highlighted the lack of sidewalks, crossings, and signage to ensure safe pedestrian access to playgrounds. Some parks that appear to be designed for children were observed to be unused by children.

2) Safety

During the interviews, most children stated that they avoided going outside, especially in the evenings, and that they felt uncomfortable in some areas because there were "older people or older brothers." Some children emphasized that there were no cameras or lighting in the parks, and therefore these areas did not feel safe.

Contrary to the principle of "eyes on the street," many public spaces observed have no active users (Jacobs, 1961). Children were observed to use parks mostly during midday hours and in large groups. This situation

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indicates that the spaces lack a sense of constant security.

3) Functional Diversity

Playgrounds in the neighborhood are mostly limited to classic park equipment such as swings, slides, and seesaws. Children stated that they found these areas boring and that they eventually moved on to other areas. In their drawings, children suggested different functions such as bike paths, climbing walls, ball courts, and animal shelters instead of seesaws, requesting more diverse and enriching spaces.

This finding indicates that children want to not only play, but also experience, explore, and socialize. At the same time, it was observed that the design of existing areas is not inclusive of different age groups and genders.

4) Belonging

In their drawings and narratives, children indicated that there are only a limited number of areas in their neighborhoods where they feel "at home." Areas directly related to daily life, such as schoolyards, market fronts, and apartment courtyards, were emphasized more frequently. However, children stated that they felt a sense of belonging to parks but could not maintain this feeling, saying things like, "We leave when other people come," or "We don't want to leave when there is trash."

Situations where a sense of belonging is strengthened are generally seen in areas where children organize themselves and spend time together (e.g., secret play spots, huts they have built themselves). This situation shows that children are more inclined to take ownership of spaces they have created themselves, rather than just the spaces provided to them.

5) Design Quality

Most of the existing parks in the neighborhood are neglected, monotonous, and designed without spatial integrity. Some children emphasized the lack of green spaces, the scarcity of trees, the unsuitability of playground equipment for their age, their fear of walking in the park in the evening, and the constant problems they encounter with traffic when going to school.

Children's own definitions of a "beautiful park" include cleanliness, vibrant colors, green elements, areas suitable for different ages, and spaces that encourage exploration. This indicates that the expectation for design quality based on user experience is at a higher level than current applications.

Picture 1. User preferences according to education levels.

Discussion

The findings of this study reveal that children's experiences of public space are shaped not only by the physical environment but also by social, cultural, and administrative factors. Children's access to space, how they perceive it, the extent to which they feel a sense of belonging, and the types of practices they develop there are examined within the theoretical framework of "spatial justice" (Soja, 2010; Harvey, 2008), "right to the city" (Lefebvre, 1996), 'visibility' (Jacobs, 1961), and "participation" (Hart, 1992).

Spatial Justice and Access

In terms of children's access to public spaces, the problem of not being able to reach quality spaces is more prominent than physical barriers. This situation shows that spatial justice is not only related to the existence of spaces but also directly related to how usable and inclusive these spaces are. The insufficient number and lack of functional diversity of existing playgrounds in the neighborhood limit children's right to access safe and meaningful spaces. These findings are consistent with the concept of spatial inequality emphasized in the literature (Soja, 2010; Harvey, 2008).

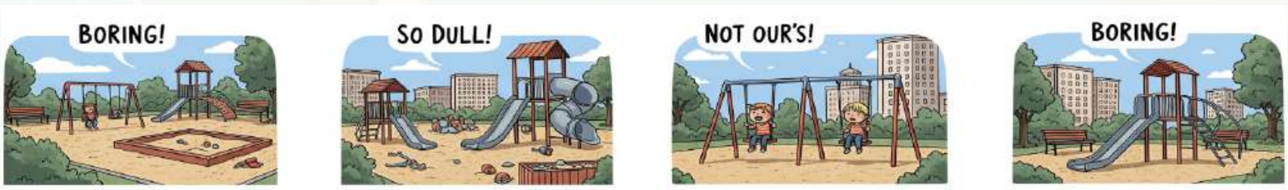
Visibility and Safety

The visibility of children in public spaces refers to both their physical presence and their social acceptance. However, research findings reveal that children are excluded as unwanted users in some areas, with adolescent boys or adults dominating these spaces. This shows that children's visibility is not only about being present but also about feeling safe and accepted. When evaluated within the framework of Jane Jacobs' concept of "the eyes of the street," it can be said that public spaces in neighborhoods lack continuous user control (Jacobs, 1961).

Participation and the Right to the City

Lefebvre's concept of "the right to the city" includes not only the right of individuals to live in the city, but also the right to participate in the processes that shape the city (Lefebvre, 1996). In this context, children's voice in the city is directly linked to their visibility and level of participation. The research revealed that children have strong perceptions of space, but these perceptions are not reflected in urban planning and design. From the perspective of the Participation Ladder model, children's experiences are mostly at the passive participation level; that is, they do not actively participate in the processes (Hart, 1992).

Belonging and Design Quality



Picture 2. Representative user comments.

The development of a sense of belonging depends on the continuous and meaningful connections children establish with space. It has been determined that children feel a greater sense of belonging in areas they have created and chosen themselves, while this connection is weaker in planned and standardized park areas. Design quality is another factor that directly affects the quality of children's experiences of space. The design elements proposed by children indicate that current practices are insufficient in terms of child-centered planning and design.

Conclusion

This study has revealed children's experiences of public spaces in Orhangazi Neighborhood and the relationship between these experiences and the concepts of spatial justice, visibility, belonging, and participation. The problems children encounter in accessing public spaces include not only physical but also social and administrative dimensions. The following recommendations are made to enable children to become active and visible actors in the city:

- Local authorities should effectively involve children in public space planning and management processes. Participatory mechanisms should be developed to ensure that children's views and suggestions are taken into account (Hart, 1992).
- Functional diversity, flexibility that takes into account age and gender differences, and natural elements should be prioritized in the design of public spaces. This can help increase children's sense of belonging and ownership.
- Lighting, cameras, and active user monitoring should be increased to ensure safety, and the continuity and liveliness of spaces should be ensured within the scope of the "eyes of the street" principle (Jacobs, 1961). In particular, vehicle traffic should be restricted to a certain area during the access of outran children to the İsa Yusuf Alptekin Primary/Secondary School in the Orhangazi neighborhood.
- Interdisciplinary cooperation and raising awareness in the context of children's rights are important for shaping policies in this direction (UNICEF, 2004).
- Access to quality public spaces should be ensured for all children in the city in a way that strengthens social inclusion and spatial justice (Soja, 2010; Harvey, 2008).

These recommendations can contribute to children becoming more visible, safe, and participatory actors in the city. Additionally, future studies are recommended to examine child-friendly city approaches in different socio-economic and cultural contexts in a comparative manner.

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Resilient Cities and Sustainable Future: Youngsters Discuss Future of the Cities

A Model for Inclusive and Sustainable Youth Empowerment – Karatay Youth Center

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ABSTRACT

This paper presents the Karatay Youth Center as a pioneering example of youth-led urban planning in Türkiye. Developed in partnership with the Karatay Youth Assembly and City Council, the Karatay Youth Center represents a participatory planning model in which young people actively shape the physical design and functional scope of the facility. Based on structured feedback from surveys, the center now offers integrated services in culture, arts, education, sports, technology and volunteering, all of which are accessible free of charge. More than a facility, the Karatay Youth Center is a model for institutionalizing youth participation in governance. The Karatay Youth Center model is strongly aligned with its core pillars of youth participation, sustainability and youth empowerment and provides a replicable governance framework for municipalities aiming to engage youth in urban development. Karatay Youth Center, which operates in the direction of inclusion, access to equal opportunities, participation and competency, which is the basic principles adopted by the United Nations about youth; it is not only an educational or activity area but also a place where young people can produce ideas and gain social responsibility awareness. Karatay Youth Center supports the individual development of young people with its workshops, trainings, activities and programs, while making them active and conscious individuals of social life.

Key words: youth empowerment, sustainable development, inclusive policy-making, youth participation,

Introduction

Young people today face many structural problems in rapidly changing urban life, ranging from access to education to employment, social exclusion, and lack of participation in decision-making processes. There is growing recognition that these problems can only be overcome not only through services specifically targeting young people, but also through their active participation in the process. Involving young people in governance processes plays a critical role not only in terms of democratic representation but also in terms of preventing social problems by increasing participation in education. Education not only reveals the full potential of young people but also serves as a protective function against negativities such as poverty, unemployment, and crime. In this context, participatory approaches that view young people not only as a target audience but also as part of the solution are in line with sustainable development goals. Karatay Municipality, one of the pioneering municipalities in Türkiye to adopt this approach, attaches great importance to youth. Considering our youth as our future, projects are being developed to implement the priorities of young people being physically and mentally healthy, educating themselves, and increasing their equipment. One of the most important ones is the establishment of Youth Centers.

Karatay Municipality emphasizes the strategic value of investing in youth, recognizing them as key actors in shaping the future. In this context, the municipality prioritizes initiatives that support the physical and mental well-being of young people, enhance their educational opportunities, and contribute to their personal development. Among the most prominent of these initiatives is the establishment of Youth Centers, which are designed to respond directly to the evolving needs and aspirations of the younger generation[1]

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Figure 1: Consultation with senior management.

It is clear that inclusive policies that respond to the changing needs and expectations of young people are being prioritized not only at the local level but also at the international level. The European Youth Strategy (2019–2027) developed by the European Commission is shaped around three fundamental principles that encourage young people to actively participate in society, strengthen their social ties, and realize their individual potential: engage, connect, and empower[2]. Since 2002, the Karatay Municipality and Youth Center have been working in line with the principles of the European Union's special Youth Policy cooperation, which supports the active participation of young people and their equal access to opportunities. Within the scope of this cooperation, policies and projects are developed to support young people in Karatay in areas such as education and employment; the capacity building of youth organizations is also provided, encouraging the active participation of young people in the region's social and cultural life[3].

The Karatay Youth Center, one of the leading examples in Türkiye that embodies these principles at the local level, offers a model in which young people are not merely service recipients but active participants in decision-making processes, through a participatory planning approach conducted in collaboration with the Karatay Youth Council and the City Council. The process of establishing the Karatay Youth Center is one of the most concrete examples of participatory design. Here, young people were not only involved as consumers but as design partners in the process; the building's functions, the needs for different spaces, and all details from seating arrangements to social areas were shaped through the direct participation of young people. The Karatay model presents an exemplary structure where young people have a say in the spatial design and their needs are directly reflected in the construction process.

The multifaceted activity areas within the center, shaped according to the suggestions of young people, such as culture, art, education, sports, volunteering, and technology, support them in forming connections with different social circles (connect), participating in social decision-making processes (engage), and developing their personal competencies (empower). In this regard, the Karatay Youth Center stands out as an outstanding local governance model that puts the core values of the European Youth Strategy into practice.

The center offers theater, music, marbling, calligraphy, painting and pencil drawing workshops; robotic coding and e-sports activities; and physical activities such as basketball, pilates, aerobics and outdoor activities. In the music workshop, students are trained in baglama, guitar, ney, violin, piano, ukulele and singing. The 80-seat library meets the academic needs of young people with unlimited internet, tablet support and nearly 10,000 resources. All these services are provided completely free of charge with an egalitarian and inclusive approach. Karatay Youth Center has sports and conference halls, E-Sports hall, classrooms, audio and silent libraries, cafeteria and all kinds of areas for the needs of young people[4].

The development of accessible and inclusive support mechanisms by local governments is critical to helping young people escape disadvantaged circumstances. Indeed, the problems faced by young people, such as poverty, difficulties in accessing education, and unemployment, can vary greatly depending on the demographic and economic structure of their cities, housing opportunities, and social support networks[5]. As emphasized by the OECD, strengthening public institutions' access to and support for young people not only creates equal opportunities, but also ensures that young people become productive and participatory members of society. Such policies also yield broad-based benefits in the long term, including poverty reduction, crime prevention, strengthened social cohesion, economic growth, and increased public trust[6]. In this context, the Karatay Youth Center supports young people in escaping these disadvantageous cycles through the comprehensive workshops and courses it offers, and stands out as an example of the transformative power of local governments. The Youth Center is not only a place where young people spend their time, but is also considered an inclusive center that transforms their lives and contributes to social development.

The multifaceted structure of the Karatay Youth Center not only involves young people in cultural and educational activities, but also directly contributes to their social, economic, and psychological empowerment. This comprehensive approach is directly aligned with the fundamental goals of the Sustainable Development Goals (SDGs). In particular, Quality Education (SDG 4), Reduced Inequalities (SDG 10), Good Health and Well-being (SDG 3), Decent Work and Economic Growth (SDG 8), Sustainable Cities and Communities (SDG 11), and Peace, Justice and Strong Institutions (SDG 16) are being implemented through concrete applications in the Karatay model[7]. The free training courses and workshops offered at the center; facilitate young people's access to knowledge, skills, and social capital, making them more resilient not only individually but also socially. Thus, the Karatay Youth Center stands out as an inclusive and transformative local government practice that enables young people to actively participate in sustainable development processes.

Karatay Municipality is a pioneer in inclusive and transformative practices at the local level with projects developed by taking into account the multidimensional needs of young people. The “Karatay Youth Project,” which was submitted within the scope of the “Youth-Friendly Cities Project Competition” organized by the Union of Municipalities of Türkiye and has a budget of 650,000 Turkish Liras, aims to provide young people living in Karatay with professional development and employment opportunities, ensure access to quality education for disadvantaged young people, and organize cultural, artistic, and sporting activities for these young people. This approach not only supports the individual development of young people but also contributes to the elimination of social inequalities and the strengthening of social solidarity.

The “Karatay Youth Entrepreneurship and Incubation Center” project, developed as an extension of these goals, aims to meet the community-based economic expectations of uneducated and unemployed young people and to increase their well-being and resilience. Thus, Karatay Municipality acts with an approach that defines young people not only as consumers but also as producers, participants, and transformative individuals. On the other hand, health-based activities such as anti-addiction awareness campaigns and first aid training are also an important part of the municipality’s inclusive approach to young people. In line with this, health experts from the Provincial Health Directorate actively contribute to the activities conducted at the Karatay Youth Center for Turkish and foreign students. This holistic model concretely demonstrates how local governments can develop effective solutions through multi-sectoral collaborations targeting youth, as exemplified by Karatay.

The themes of “Participation,” “Development,” and “Peace” adopted by the United Nations in 1985 as part of the International Year of Youth remain universal principles that are still relevant today. Accordingly, the Karatay Municipality Youth Center supports young people’s active participation in social life, encourages their involvement in local development processes, and contributes to the construction of a peaceful and inclusive society. Providing young people with areas of responsibility not only contributes to their individual development but also strengthens Karatay’s social, cultural, and economic structure. Because young people represent the future of society; today’s youth are in a position to shape the direction of society as tomorrow’s decision-makers[8].

Methodology

This study adopts a participatory and youth-centered methodology, combining both qualitative and quantitative data collection techniques. Through structured surveys and collaborative planning processes, the perspectives of young people were systematically integrated into the planning and implementation of the Karatay Youth Center. Institutional cooperation between the Youth Assembly and the City Council ensured that youth voices translated into concrete urban outcomes.

Main Results

The needs and demands of youth in Karatay were systematically gathered through surveys, workshops, and meetings facilitated by the Karatay Youth Assembly in cooperation with the City Council. As a result, the construction of the Karatay Youth Center was designed based on direct feedback from young people. Karatay Youth Center offers a rich range of opportunities for the different interests and needs of young people. Common administrative offices are planned for both the Youth Assembly and the City Council, providing an environment of continuous cooperation between young people and local administrators.

The experience of Karatay Youth Center clearly demonstrates the critical role that local governments can play in the effective implementation of youth policies on the ground. To date, 2,496 students have participated in 37 workshops organized at the center, 450 young people have actively participated in E-sports and 7 different lecture/meeting halls have been made available to young people. These quantitative indicators reveal that the center is not only a physical space, but also plays an active role in the social participation, skill development and community building processes of young people.

In this context, the active participation of young people in research processes through Youth Participatory Action Research (YPAR) and the creation of solutions by setting their own agendas have strong academic parallels with youth-centered structures such as the Karatay Youth Center.
Indeed, the fact that today's youth face the risk of living in less prosperous conditions than their parents since the Second World War makes local empowerment of youth policies an urgent social priority[9]. Across Europe, 29% of young people aged 16-29 are at risk of poverty or social exclusion, while 11.6% of 15-24 year olds are not in education, employment or training (NEET)[10] and 15.9% are unemployed, twice as many as the general population[11]. These data show that socio-economic and democratic exclusion go hand in hand, thus youth centers should not only promote individual development but also social inclusion.

The expansion of inclusive and participatory centers such as Karatay Youth Center across the country will not only unleash the potential of young people, but also reinforce the transformative power of local governments in the fight against social inequalities.

The sustainable, inclusive and participatory youth services implemented through Karatay Youth Center are an inspiring "good practice example" not only for young people in Karatay, but also for other municipalities.

Karatay Youth Center's experience to date clearly demonstrates the decisive role that local governments can play in the effective and target-oriented implementation of youth policies in the field. The activities carried out at the Center not only help young people develop their individual talents, but also encourage them to gain a sense of social responsibility and participate in decision-making processes. In this respect, Karatay Youth Center has a participatory approach that sees young people not only as beneficiaries but also as active stakeholders.

Therefore, the dissemination of such centers across the country should be considered as an important strategy not only to unleash the potential of young people, but also to strengthen democratization and social inclusion at the local level. The Karatay example stands out as a successful model that makes visible the impact and transformative capacity of local governments in the field of youth.

Table 1. Karatay Youth Center in Figures

Indicators	Value
Total Number of Workshops	37
Total Number of Students	2496
Number of E-Sports Participants	450
Lecture Hall/Meeting Room	7 units

(Source: Karatay Belediyesi Gençlik Merkezi [Internet]. [cited 2025 Jul 24]. Available from: https://genclikmerkezi.karatay.bel.tr/)

Figure 2: Result video QR Code

Conclusion

The Karatay Youth Center stands out as a participant-driven, holistic facility that truly addresses the voiced needs of local youth. By embedding the design and priorities within youth-led workshops and surveys, the project ensured high levels of relevance and acceptance. Its multifunctional layout—spanning education, culture, art, technology, sports, and social interaction—supports a well-rounded developmental environment. Offering all services free of charge enhanced accessibility, demonstrating a commitment to equity and youth empowerment aligned with Cities4Youth's core values of inclusivity, sustainability, and participatory policy-making . Moreover, the center serves as a hub that reinforces community bonds through volunteer programs, cultural activities, and counseling services, embedding social impact and civic engagement at its core. This model provides an effective and replicable roadmap for municipalities: the youth-led planning process is supported by free and varied programs; concrete and sustainable results are achieved through continuous collaboration between the youth council and municipal authorities.

The structure offered by Karatay Youth Center is strongly aligned with the main objectives of not only national but also European youth policies. Among the priorities identified within the framework of the European Youth Strategy;

- To enable young people to become the architects of their own lives,
- To increase their resilience and build life skills,
- Encouraging them to contribute to active citizenship and positive social transformation inspired by EU values,
- Preventing social exclusion,
- Integrating the needs of young people into decision-making processes through intersectoral dialogue[12].

The practices developed by Karatay Municipality in this direction make concrete contributions to the European Youth Vision at the local level and demonstrate strategic alignment.

In addition, the governance mechanisms developed at the center are in line with SDG 16.7 - Ensuring responsive, inclusive, participatory and representative decision-making processes at all levels, which is included in the Sustainable Development Goals (SDGs). Karatay City Council and Municipality

Assembly and Karatay Youth Center directly serve this goal with their structures and working methods that institutionally strengthen youth participation. This holistic approach was also included in the 2021 Voluntary Local Review (VLR) report of Karatay Municipality and was defined as a successful practice for sustainable development at the local level[13].

In conclusion, the Karatay Youth Center model is an exemplary youth policy implementation where the needs and expectations of young people are at the center and participatory governance is integrated with spatial planning and inclusive service understanding. While this model ensures the active participation of young people in social life, it also has strategic importance in terms of democratization at the local level, strengthening social inclusion and increasing social solidarity. This good practice model, which can serve as an example for other local governments in Türkiye, offers a sustainable approach that unlocks the potential of young people and brings them into society as productive and transformative individuals.

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Perceptions of International Students Living in Sakarya Regarding the City for Learning Turkish as a Foreign Language

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ABSTRACT

This study aims to evaluate the extent to which Sakarya qualifies as an "international education city" by analyzing This study aims to evaluate the extent to which Sakarya qualifies as an "international education city" by analyzing the experiences of international students studying in Sakarya to learn Turkish as a foreign language. The main objective of the study is to determine students' perceptions of accommodation, transportation, social integration, access to public services, and overall life satisfaction, and to develop policy recommendations accordingly. The research was designed using a quantitative methodological approach, and a questionnaire was used as the data collection tool. A pool of survey questions was created, and the opinions of two experts were sought. The questions were revised based on the experts' opinions and finalized. The survey consists of 22 questions and includes multiple-choice and open-ended questions on accommodation, transportation, social life, safety, and general evaluation, in addition to participants' demographic information. The findings indicate that Sakarya is generally evaluated positively in terms of accommodation facilities, transportation convenience, and safety; however, the lack of social activities and difficulties in communicating with the local community make the adaptation process challenging for some students. These results highlight the need to develop internationalization policies in the city and the importance of enhancing university-city collaboration.

Key words: International Students, cities, city of education, young people's perception of the city

Introduction

In today's world, where globalization is accelerating, higher education institutions are directly affected by internationalization processes, and in this context, international student mobility is increasing every day. According to UNESCO (2023) data, approximately 6 million students worldwide are studying in a country other than their own. This mobility not only enables students to acquire academic knowledge but also allows them to engage in different cultural environments and gain new life experiences. Altbach and Knight (2007) state that international students make significant contributions to their personal development in this process; however, they also face various challenges in adapting to cultural, social, and economic environments (Altbach & Knight, 2007, p. 291). In this regard, the living conditions offered by the cities where international students study directly affect both their satisfaction levels and the city's potential to become an "international education city." In addition to providing economic contributions to host countries, international students also enrich the academic and cultural environment of universities. The OECD's (2020) Education at a Glance report emphasizes this contribution by stating, "International students not only contribute economically to host countries but also enrich the academic and cultural environment of universities" (OECD, 2020, p. 34). However, living in a different country and city presents both opportunities and challenges for students. Zhou et al. (2008) note, "Living and studying in a foreign country can be both an exciting and stressful experience for international students, often influenced by cultural differences, language barriers, and lack of social support," drawing attention to the main difficulties faced by international students (Zhou, Jindal-Snape, Topping, & Todman, 2008, p. 63). These challenges often concentrate on essential aspects of life such as housing, transportation, social life, safety, and access to public services, directly affecting students' overall life satisfaction.

The infrastructure and services provided by cities play a decisive role in the integration and satisfaction levels of international students. Anderson (2008) highlights the critical role of city living conditions in student satisfaction, stating, "The level of integration and satisfaction among international students is strongly related to the living conditions and services offered by the city where the university is located" (Anderson, 2008, p. 45). Similarly, Knight (2012) underlines the importance of cities providing inclusive and accessible environments in the internationalization process by stating, "Host cities play a critical role in internationalization of higher education by creating inclusive, accessible, and welcoming environments" (Knight, 2012, p. 23). Particularly, factors such as affordable housing, reliable transportation, and accessible public services are key to increasing international student satisfaction. Glass and Westmont (2014) stress the importance of these elements by stating, "A supportive city infrastructure that includes affordable housing, reliable transportation, and accessible public services significantly impacts the overall satisfaction of international students" (Glass & Westmont, 2014, p. 44).

This study aims to analyze the extent to which Sakarya, one of Turkey's prominent university cities, possesses the qualities of an "international education city" from the perspective of international students. With its geographical location, university infrastructure, and cultural diversity, Sakarya has the potential to be an attractive destination for international students. However, the extent to which this potential is realized depends on the experiences and perceptions of the international students living in the city. In this context, the study will quantitatively assess the experiences and perceptions of international students learning Turkish as a foreign language in Sakarya regarding city life. By examining the opportunities and challenges students face in key areas such as housing, transportation, social life, safety, and access to public services, the study aims to identify Sakarya's strengths and weaknesses in its path to becoming an international education city.

This analysis will not only evaluate Sakarya's current situation but also contribute to the development of policies aimed at enhancing the potential of cities to become international education hubs. Cities that increase international student satisfaction not only support the internationalization processes of higher education institutions but also gain a competitive advantage in the global education market. Therefore, developing an inclusive and supportive infrastructure that meets the needs of international students will provide long-term benefits for both students and the city itself.

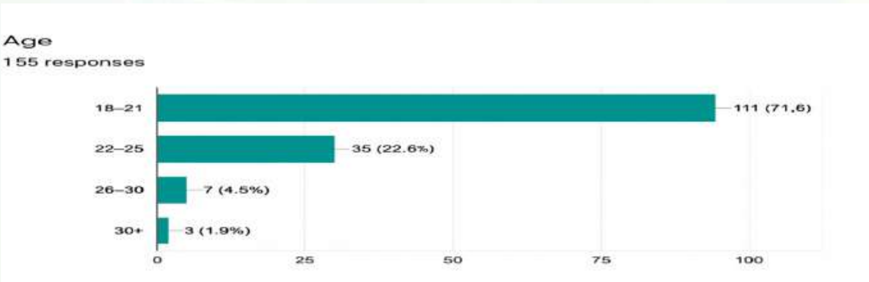
Methodology

This research aims to evaluate the status of Sakarya as an "international education city" by examining the living experiences of international students studying in the province. The study is designed within the framework of the quantitative research method. Quantitative research is a systematic approach that aims to measure and analyze phenomena through numerical data (Creswell, 2014). In this context, the survey technique was chosen as the data collection tool. The survey method is an effective and economical means of gathering data from many participants, identifying trends, and conducting comparative analyses (Dörnyei, 2007). The questionnaire used in the study was developed based on a literature review and similar studies. After the draft form was prepared, feedback was sought from two academics specializing in teaching Turkish as a foreign language and in the field of internationalization in education. In line with the feedback received, some statements were simplified, and certain questions were removed or revised to improve clarity. This process was carried out to enhance the validity and reliability of the data collection tool (Fraenkel, Wallen & Hyun, 2012). In its final form, the questionnaire consists of questions related to participants' demographic information, housing conditions, transportation facilities, social integration, safety, access to public services, and overall life satisfaction. It includes both closed-ended (Likert-scale and multiple-choice) and open-ended questions. The open-ended questions allowed students to share their experiences in their own words, thus providing a basis for qualitative interpretation. The study sample was determined using the simple random sampling method among international students studying Turkish as a foreign language at universities in Sakarya. This method is considered reliable and objective as it gives each individual an equal chance of being selected (Büyüköztürk et al., 2012). Data analysis was conducted using descriptive statistics (frequency, percentage, mean). In addition, responses to open-ended questions were thematically categorized and interpreted using descriptive analysis technique.

Study Group

Participants come from 30 different countries, which are as follows:
Indonesia, Kenya, Russia, Jordan, Pakistan, Palestine, Kazakhstan, Tunisia, Azerbaijan, Mauritania, Tanzania, Afghanistan, Türkiye, Saudi Arabia, Somalia, Iraq, Yemen, Congo, Egypt, Algeria, China, Syria, Thailand, Eswatini, Colombia, Cameroon, Iran, Kyrgyzstan, Libya, Malaysia. In addition, some participants identified their nationality not as a specific country but in terms of their ethnic or regional identity, such as: Circassian, Arab, Kazan Tatar, Turkmen, Crimean Tatar. From the participants, the following questions were asked:

Table 1: Age



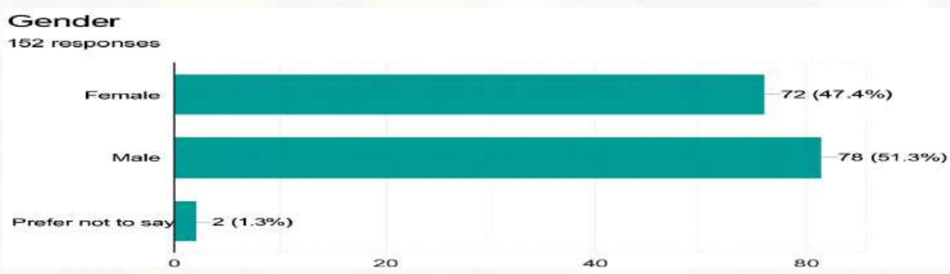
Age Range 18–21: This range constitutes by far the largest group, with 85 out of a total of 133 records. This indicates that the majority of participants are young people of typical university age.
Age Range 22–25: The second-largest group, consisting of 35 participants. This suggests that some participants may be in the final years of their undergraduate studies or at the beginning of their graduate education.

Age Range 26–30: This group includes 9 participants. Although smaller in number, it may consist of individuals pursuing postgraduate studies or those at the early stages of their careers.

Age Range 30+: The smallest group, with only 4 participants. This reflects a small number of individuals continuing their education at a later stage in life or following an alternative career path.

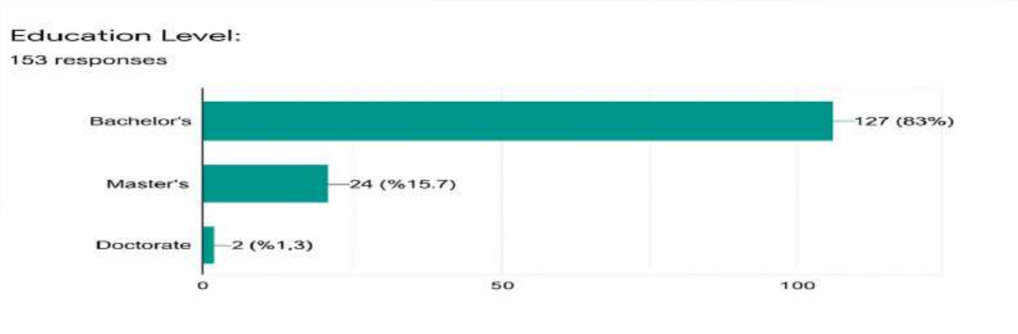
Others: Some participants did not disclose their age.

Table 2: Gender



Male participants: 72, female participants: 78, participants who preferred not to disclose their gender: 2

Table 3: Education Level



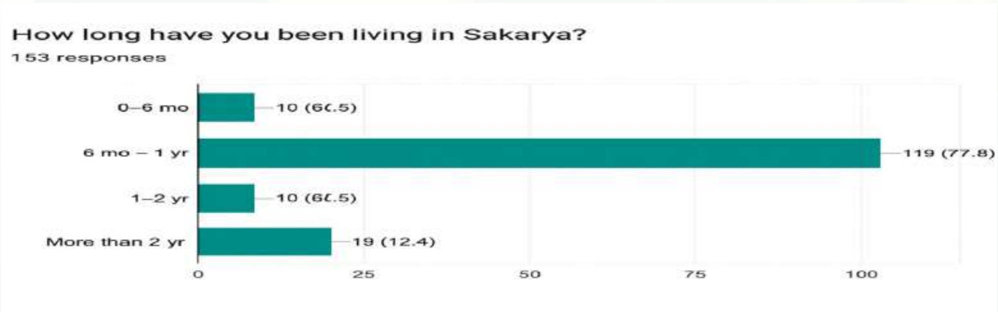
The study included 136 undergraduate participants, along with 16 at the master's level (as indicated in the sources), and 2 at the doctoral level.

Main Results

Quantitative Results

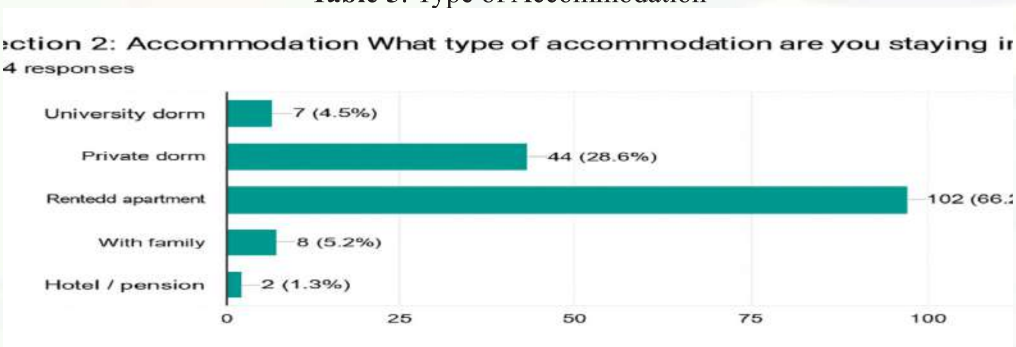
The results of the survey completed by the participants are as follows:

Table 4: Length of Stay in Sakarya



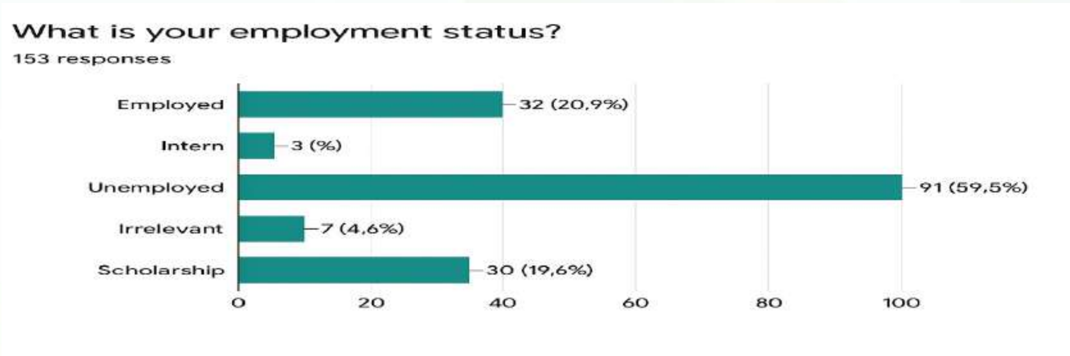
6 months – 1 year: This category represents by far the highest proportion, with 106 records.
More than 2 years: The second-largest group, consisting of 18 participants.
0 – 6 months: This group includes 9 participants.
1 – 2 years: This range includes 7 participants.

Table 5: Type of Accommodation



Among the different accommodation types reported in the survey, rented apartments or houses were the most common, mentioned 65 times, including both participants who selected only this option and those who combined it with others (e.g., "university dormitory, rented apartment"). The second most frequent type was private dormitories, recorded 32 times, again covering both single and combined mentions. In comparison, university dormitories were cited 8 times, living with a host family appeared 6 times, and hotels/guesthouses were noted only 2 times.

Table 6: Employment Status



The majority of students surveyed were found not to be employed. Scholarship recipients constituted a notable proportion, while the number of participants who were working or undertaking internships was considerably smaller.

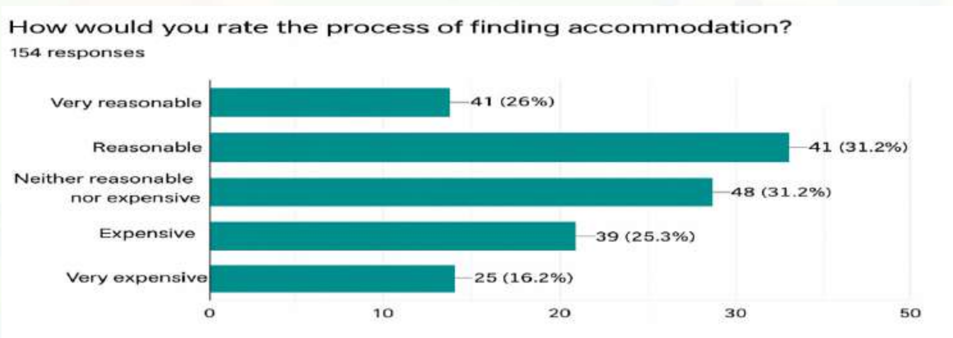
Not working: 61 participants. This category includes those who indicated only "Not working" as well as those listed in combination with other statuses (e.g., "Intern, Not working" or "Not working, Scholarship recipient"). This suggests that a large portion of the participants are focused primarily on their studies and are not actively engaged in employment.

Working: 26 participants. Although fewer in number compared to non-working students, this figure still shows that a portion of students balance employment alongside their studies. Combinations such as "Working, Scholarship recipient" are included here.

Scholarship recipient: 22 participants. This indicates that a significant proportion of students finance their education through scholarships. Some cases overlap with other categories (e.g., "Working, Scholarship recipient" or "Not working, Scholarship recipient").

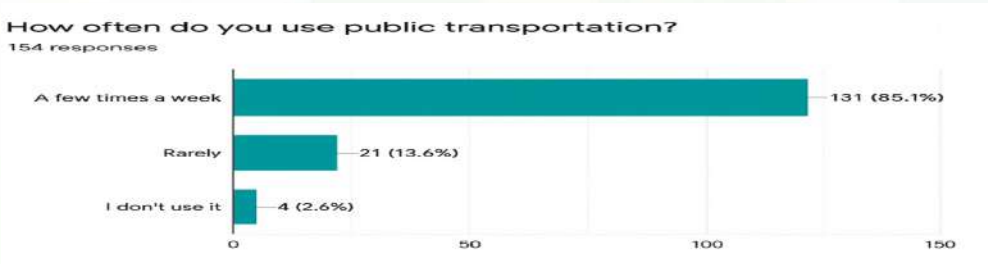
Intern: 3 participants. This small number suggests that internships are uncommon among participants, or that the survey period did not coincide with active internship placements. One participant was listed as "Intern, Not working".

Table 7: Evaluation of Accommodation Pricing



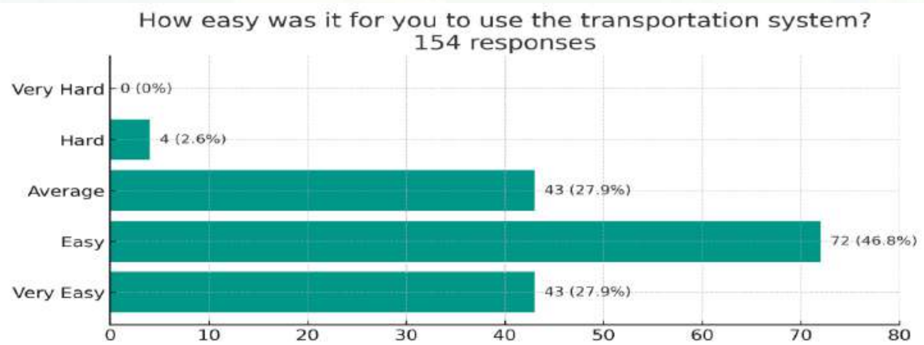
Analysis of accommodation cost perceptions showed that the most common response was "neither cheap nor expensive" (n=48), indicating a moderate experience in terms of both cost and difficulty. "Expensive" was reported by 40 participants, suggesting potential affordability issues, particularly for international students, while 35 participants described costs as "affordable". A smaller group considered accommodation "very expensive" (n=19), reflecting significant financial constraints, and 13 participants found it "very affordable". Some respondents selected multiple categories, indicating nuanced or multi-dimensional perceptions of the accommodation search process.

Table 8: Use of Public Transportation in Sakarya



The majority of participants (**85.1%**, 131 students) reported using urban transportation in Sakarya several times a week. A smaller portion (**13.6%**, 21 students) use it rarely, while only **2.6%** (4 students) stated that they never use public transport.

Table 9: Ease of Using the Transportation System



Nearly half of the participants (46.8%, 72 students) found the transportation system "easy" to use, while 27.9% (43 students) rated it as "very easy" and another 27.9% (43 students) as "moderate." Only 2.6% (4 students) reported it as "difficult," and none rated it as "very difficult."

Table 10: Evaluation of Transportation Fees

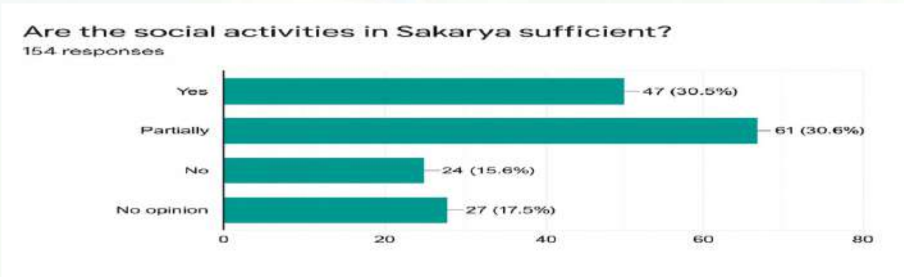
Almost half of the participants (**48.7%**, 75 students) rated transportation fees as "affordable," while **27.3%**

(42 students) considered them "very affordable." About **20.8%** (32 students) viewed them as "neither cheap nor expensive," and only **8.4%** (13 students) found them "expensive." No participants rated the fees as "very expensive."

Table 11: Availability of Student Discounts in Transportation

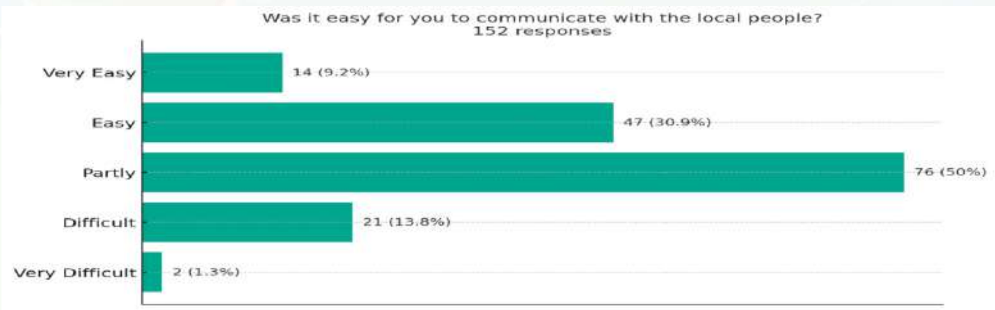
A large majority of participants (**86.5%**, 134 students) stated that student discounts are available for transportation in Sakarya. A small proportion (**4.5%**, 7 students) said there are no discounts, while **9%** (14 students) were unsure.

Table 12: Sufficiency of Social Activities in Sakarya for Social Life and Integration



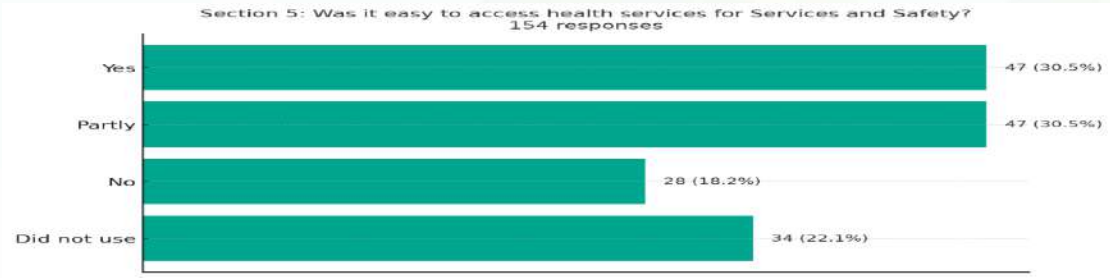
Regarding the adequacy of social activities in Sakarya, **39.6%** (61 students) responded "partly," while **30.5%** (47 students) answered "yes." About **15.6%** (24 students) considered them insufficient, and **17.5%** (27 students) had no opinion.

Table 13: Ease of Communication with Local People



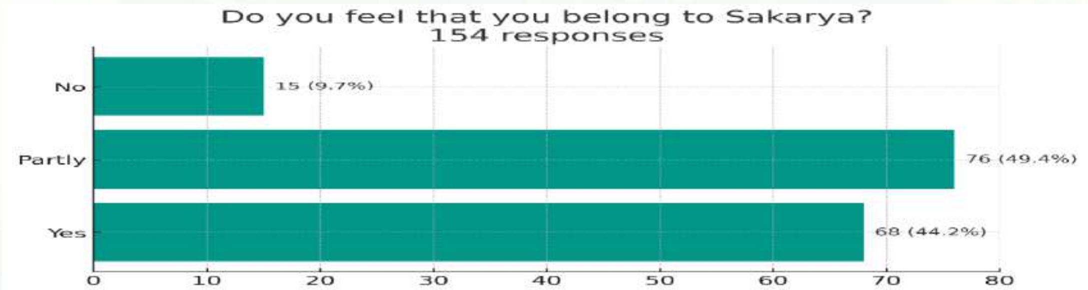
Half of the participants (**50%**, 76 students) reported that communicating with locals was "partly" easy. About **30.9%** (47 students) found it "easy," while **9.2%** (14 students) considered it "very easy." A smaller share experienced difficulties, with **13.8%** (21 students) stating it was "difficult" and **1.3%** (2 students) finding it "very difficult."

Table 14: Ease of Access to Health Services in Terms of Services and Safety



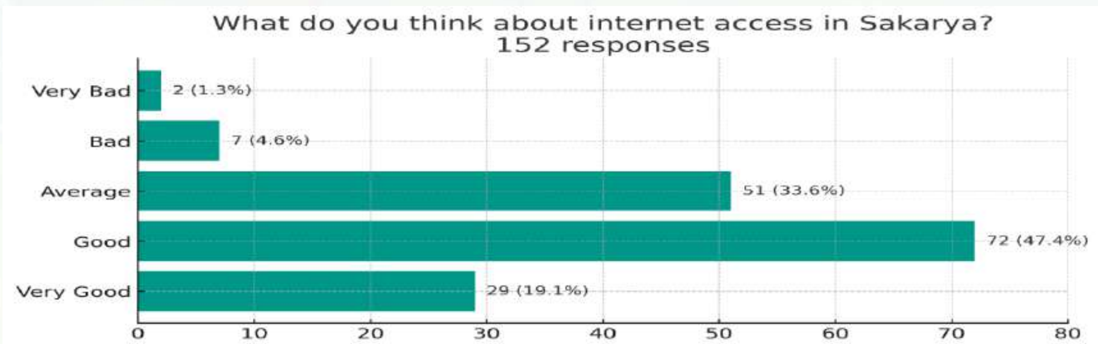
An equal proportion of participants (**30.5%**, 47 students each) stated that accessing healthcare services in Sakarya was either "easy" or "partly" easy. Meanwhile, **18.2%** (28 students) reported difficulty, and **22.1%** (34 students) had not used healthcare services at all.

Table 14: Sense of Belonging to Sakarya



Nearly half of the participants (**49.4%**, 76 students) reported feeling "partly" a sense of belonging to Sakarya, while **44.2%** (68 students) said they do feel a sense of belonging. Only **9.7%** (15 students) stated that they do not feel connected to the city.

Table 15: Opinions on Internet Access in Sakarya



Nearly half of the participants (47.4%, 72 students) rated internet access in Sakarya as "good," while 33.6% (51 students) considered it "moderate" and 19.1% (29 students) as "very good." A small proportion rated it negatively, with 4.6% (7 students) saying "poor" and 1.3% (2 students) saying "very poor.

Qualitative Findings

Most Liked Aspects of Sakarya

According to the qualitative findings, the aspects of Sakarya that international students most appreciate include the city's tranquility, natural beauty, and recreational areas, especially Lake Sapanca. Additionally, the academic quality of Sakarya University, the campus environment, the warm and hospitable attitude of the people, the relatively affordable cost of living, and the ease of transportation are frequently mentioned. The fact that the city is far removed from the hustle and bustle of large metropolises is also highlighted as a positive feature by the students. These findings suggest that Sakarya offers an environment that is peaceful, safe, and easy to adapt to, making it an ideal place for international students.

Challenges Faced in Sakarya

The challenges faced by international students in Sakarya are concentrated in various areas. The primary issue is accommodation and finding housing. Participants pointed out the high rental prices, the constant rent increases, and the limited number of available apartments as the major difficulties. The distance of dormitories from the university and the inadequacy of public transportation options are also additional problems related to accommodation.

The second major challenge is the language and communication barrier. Students, especially when they first arrive, struggle to communicate due to the lack of English speakers and view the difficulty of learning Turkish as a factor that further complicates the process. Misunderstandings during street-level communication and the lack of foreign language support during official procedures make the adaptation process more challenging for students.

The limited transportation options are another frequently mentioned problem. The limited number of bus schedules, overcrowded buses, expensive minibus fares, and the lack of alternative transportation options make daily life difficult for students.

Lastly, access to healthcare services has been problematic for some students. Difficulties in finding the right specialists, the high cost of dental care, and certain deficiencies in the healthcare system were highlighted as issues faced by students.

These findings indicate that the living experiences of international students in Sakarya are not solely characterized by positive aspects. They face significant challenges in areas such as accommodation, language, transportation, cost of living, and social integration.

Advice for New International Students

Students who participated in the research offered various recommendations for those who will be coming to Sakarya in the future. The most frequently mentioned piece of advice is to prioritize learning Turkish. Students noted that mastering the language would ease the adaptation process and reduce communication barriers in daily life. They emphasized that language practice should be supported not only through programs like TÖMER but also through personal effort and daily interactions.

The second key recommendation is the importance of preparation and planning. Participants suggested that students should complete necessary paperwork, secure health insurance, research the city's characteristics, and prepare financially before arriving in Sakarya.

Students also advised newcomers to be patient and open-minded, stating that understanding cultural differences could facilitate their social adaptation. Additionally, regular attendance in classes and fulfilling academic responsibilities without delay were emphasized as important for academic success.

Moreover, some students warned about potential risks. They highlighted the need to be cautious of fraud, the high cost of living in the city, and pointed out that Sakarya may not be suitable for every student.

Overall, the students' advice focuses on language learning, financial and academic preparation, cultural adaptation, and openness to social relationships.

Conclusion

This study shows that Sakarya has many characteristics of a developing "international education city" with its strengths such as ease of transportation, affordability, safety, and accommodation options for those who will learn Turkish as a foreign language. However, there are still difficulties in areas such as providing social activities, language barriers, and access to certain services. While many students feel a sense of belonging to some extent, full integration remains limited. Making housing more affordable, expanding cultural and recreational opportunities, and improving support services will be crucial to strengthening Sakarya's role in the global education market and enhancing the satisfaction of international students.

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Resilient Cities and Sustainable Future: Youngsters Discuss Future of the Cities

Autism-Friendly Urban Innovation: Enhancing Social Resilience for Neurodiverse Youth in Sakarya

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ABSTRACT

This study presents an urban resilience model reinforced by social innovation to promote fair and inclusive participation of individuals with autism in city life in Sakarya. The research identifies major barriers such as sensitivity to sensory stimuli, lack of guidance, insufficiently trained public personnel, and spatial discrimination. Based on the World Health Organization's (WHO, 2023) autism policies, DSM-5 diagnostic criteria, meta-analyses, field observations, and intercultural case studies, the paper proposes solutions including sensory-friendly areas, icon-based guidance systems, trained public personnel, and participatory governance mechanisms.

The proposed model aligns directly with the United Nations Sustainable Development Goals (SDG) 10 (Reduced Inequalities) and SDG 11 (Sustainable Cities and Communities). Recommendations for Sakarya include mobile support teams for rural access, autism-friendly architectural applications, community awareness workshops, and ASD-certified public institutions. Findings show that inclusive design enhances social resilience not only for autistic individuals but for all residents.

Key words: Autism Spectrum Disorder, Urban Innovation, Social Resilience, SDG 11, Sakarya

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by differences in social communication, interaction, and behavior patterns. Elements of urban life such as intense light, noise, and crowds can trigger anxiety, stress, and feelings of exclusion in autistic individuals. In Turkey, urban planning processes are generally designed for neurotypical individuals, making cities physically and socially inaccessible for the neurodiverse.

Sakarya, with its rapidly growing infrastructure and evolving social life, is a critical example of how to integrate neurodiverse individuals into community life. This study aims to identify autism-friendly urban innovation approaches and develop solutions that enhance social resilience in Sakarya.

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Methodology

-Data Sources: WHO (2023) Autism Policies, DSM-5 diagnostic criteria, CDC data, The Lancet Psychiatry (2023) GBD statistics.
- Research Methods: Literature review, meta-analysis evaluations, field observations, local situation analysis.
- Analytical Framework: Urban innovation and social resilience principles aligned with SDG 10 and SDG 11.

Main Results and Discussion

The study defines four primary intervention areas based on DSM-5, WHO 2023 reports, and local situation analyses. These intervention areas, informed by field observations, literature reviews, and intercultural examples, are compatible with both local and global strategies.

1. Sensory-Friendly Spaces:

- Proposals include quiet corridors in city parks, transport stops, and school areas with noise levels below 60 dB and lighting below 500 lux. Similar implementations in cities like Sheffield and Amsterdam have improved emotional regulation in autistic children (Evans et al., 2021).

2. Mobile Access and Rural Support:

- Due to the scarcity of special education centers in rural districts of Sakarya, mobile support teams and digital consultancy platforms (e.g., Project ECHO) are recommended. These systems provide support without requiring travel to central facilities.

3. Public Education and ASD Certification:

- Only 20% of municipal personnel in Turkey have received autism-related training. Therefore, autism awareness programs and ‘Autism-Friendly Institution Certification’ should be developed. This will enhance service quality and reduce discrimination.

4. Participatory Governance:

- Advisory councils where autistic individuals and their families play active roles should be established within Sakarya Municipality. These mechanisms enhance societal empathy and generate user-centered solutions.

Table 1. Autism Prevalence Data for the World and Turkey (per 100,000 population)

Region / Group	Prevalence	Male	Female	Male/Female Ratio
Global Avg.	788	1065	508	4.3:1
Turkey (Middle-Income Europe & Central Asia)	~826	-	-	-
High-Income Asia-Pacific	1559–1560	-	-	-
USA, Canada, EU	~1090	-	-	-

Prevalence By Age:
0–4 years: 169 | 0–19 years: 163 | 20+ years: 137 per 100,000

Regional Breakdown:
High-income Asia-Pacific (e.g., Japan, South Korea): ~1,559–1,560
General high-income countries (US, Canada, EU): ~1,090
Middle-income Europe & Central Asia (incl. Turkey): ~826
Latin America & Caribbean: ~743 | Southeast & East Asia: ~669
Tropical Latin America & Bangladesh: ~500–600 (lowest)

Special Educatıon Centers In Sakarya

Figure 1. Estimated Special Education and Rehabilitation Centers in Sakarya Districts (2025)

Sakarya Special Education and Rehabilitation Centers

There are approximately 120 special education and rehabilitation centers in Sakarya, which is numerically adequate compared to other mid-sized cities in Turkey. However, from a perspective of social innovation and urban resilience, not only quantity but also quality, accessibility, inclusive design, and municipal integration are essential.

Autistic individuals need not only educational interventions but also sensory-sensitive environments, community-based participation, and family support mechanisms. The literature emphasizes user involvement in service design processes (Mulgan, 2006; WHO, 2023). Many centers in Sakarya focus on individual therapy but lack multi-stakeholder projects, integrated support services, and resilient spatial access systems. Moreover, service access inequality is observed, with central districts like Adapazarı and Serdivan having more facilities than rural districts like Geyve or Kocaali.

Recommendations:
- Design of sensory-friendly centers
- Mobile support teams
- Accessibility programs for rural districts
- Family-centered resilience projects

Table 2. Autism-Friendly Urban Features and Implementation Roadmap

Intervention Area	Description	Stakeholders
Quiet Corridors, Quiet Parks	Noise <60 dB, light <500 lux, green buffer areas	Municipality, urban planners
Sensory-Friendly Classrooms	Adjustable lighting, acoustic arrangements	Ministry of Education, autism experts
ASD-Friendly Schools	Integration of sports, occupational therapy, and special education	Special Education Centers
Online Support	Digital consultancy platforms such as Project ECHO	Healthcare institutions

Conclusion

True urban resilience is possible through a design and governance approach that embraces cognitive diversity. By adopting an autism-friendly urban innovation model, Sakarya can enhance the quality of life not only for autistic individuals but for all its residents.

Acknowledgment:

This work is dedicated to all individuals and institutions in Sakarya who support autistic individuals instead of isolating them. Special thanks to the sensitive friends who touch the lives of autistic children.

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QR CODE RECOGNITION AND AUTOMATION BASED RECYCLING BIN

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ABSTRACT

This study focuses on the development of a QR code recognition and automation-based recycling bin system to support sustainability and environmental awareness within the context of urban transformation. Designed as an innovative response to increasing waste management challenges brought about by urbanization, the system aims to encourage recycling behavior through interactive and technological engagement. The project was implemented in five key phases. In the first phase, a 3D model of the recycling bin was created using Tinkercad software and produced with a 3D printer. In the second phase, the electronic system was assembled using an Arduino Uno, QR code scanner, servo motor, LED light, and buzzer. In the third phase, a custom algorithm was developed in the Arduino IDE environment to detect waste types and assign reward points to users based on QR code identification. The fourth phase involved testing the system in a school environment, observing both user interaction and technical functionality. In the final phase, user feedback was collected and evaluated. The results demonstrated that the system effectively increased recycling awareness, promoted student engagement, and fostered environmental responsibility. With its low-cost, scalable, and educational design, the project offers a practical and sustainable infrastructure model that can be integrated into urban transformation initiatives, while also supporting the development of students' STEM-based skills.

Key words: Urban transformation, QR code automation, sustainability, smart infrastructure, STEM education

Introduction (Introduction, Methodology, Main Results, Conclusion, References):

Global trends such as urbanization, industrialization, and population growth have significantly increased the volume of waste generated worldwide. According to the World Bank, the amount of global solid waste, which was 3.5 million tons per day in 2016, is projected to rise to 6 million tons by 2050 (Hoornweg & Bhada-Tata, 2012). This alarming increase necessitates the development and implementation of sustainable waste management techniques. In urban areas particularly, the accumulation of waste leads to critical challenges, including resource depletion, environmental degradation, and adverse public health impacts (Kaçtoğlu & Şengel, 2010).

Although conventional waste sorting methods have provided partial solutions, they are often costly, time-consuming, and prone to human error (Yılmaz & Bozkurt, 2010). Additionally, the inaccessibility of current systems for individuals with disabilities further hinders the achievement of sustainable development goals (Fidan, 2014; Çelik & Topsakal, 2017). Inefficient municipal waste management can result in leachate pollution, increased greenhouse gas emissions, and the waste of non-renewable natural resources. Therefore, a comprehensive approach to municipal waste management is imperative (Zaman, A. U., 2014).

Recent advances in technology—specifically Artificial Intelligence (AI), the Internet of Things (IoT), and automation—have increasingly been integrated into waste management procedures. These technologies enable accurate waste separation, reduce human error, accelerate the process, and lower operational costs (Zhang et al., 2021; Kumar et al., 2020). However, many of the automated sorting systems currently in use are not accessible to people with disabilities, thereby limiting social inclusion and undermining broader sustainability efforts. This situation poses a substantial barrier to achieving the United Nations Sustainable Development Goals (SDGs), particularly the objective of creating “Accessible and Sustainable Cities” (UN, 2015).

Conventional waste sorting techniques are proving inadequate in urban contexts, primarily due to inaccurate classification, which lowers recycling rates and increases environmental pollution. In this regard, it is essential to develop sustainable waste management solutions. This study proposes a methodology that not only integrates technological advancements into waste management practices but also preserves the values of accessibility and social equity. The findings may shape the future of waste management techniques by emphasizing the importance of social and environmental sustainability. In this context, the study offers insights not only for scholars but also for companies, non-governmental organizations, and local governments.

Methodology

In this study, a prototype of an intelligent waste sorting system based on symbol recognition and automation was designed and developed to address the prevalent issues of improper segregation and inefficient recycling in waste management processes. The autonomous system incorporates a camera module capable of detecting QR codes uniquely assigned to each waste category (e.g., plastic, glass, packaging, batteries). Upon detecting the QR code on the waste item via the camera, the system automatically opens the lid of the corresponding recycling bin, ensuring the waste is accurately deposited into its appropriate category.

This method allows for error-free classification and routing of waste, effectively eliminating cross-contamination between categories and reducing the additional sorting costs incurred at recycling facilities. The physical prototype was initially modeled using Tinkercad and refined through Creality Print before being fabricated with a 3D printer. The result was a fully functional and aesthetically optimized design, engineered for durability and seamless lid actuation.

Figure 1. Prototype Printed with a 3D Printer

To develop the QR recognition system, the locally manufactured **Deneyap microcontroller board** and **Deneyap Camera Module** were employed. Custom commands were programmed using the Arduino software language, enabling the camera to scan QR codes, process the embedded data, and transmit it to the Deneyap board. The microcontroller then interpreted the input and activated the appropriate servo motor via jumper wires connected to a breadboard, directing the waste item to the correct compartment.

Accessibility was a core design criterion throughout the system's development. For users with visual impairments, audible feedback mechanisms were integrated, while visual indicators such as LED signals were incorporated to assist users with hearing impairments. These features ensure the system is inclusive, user-friendly, and accessible to individuals with diverse physical needs.

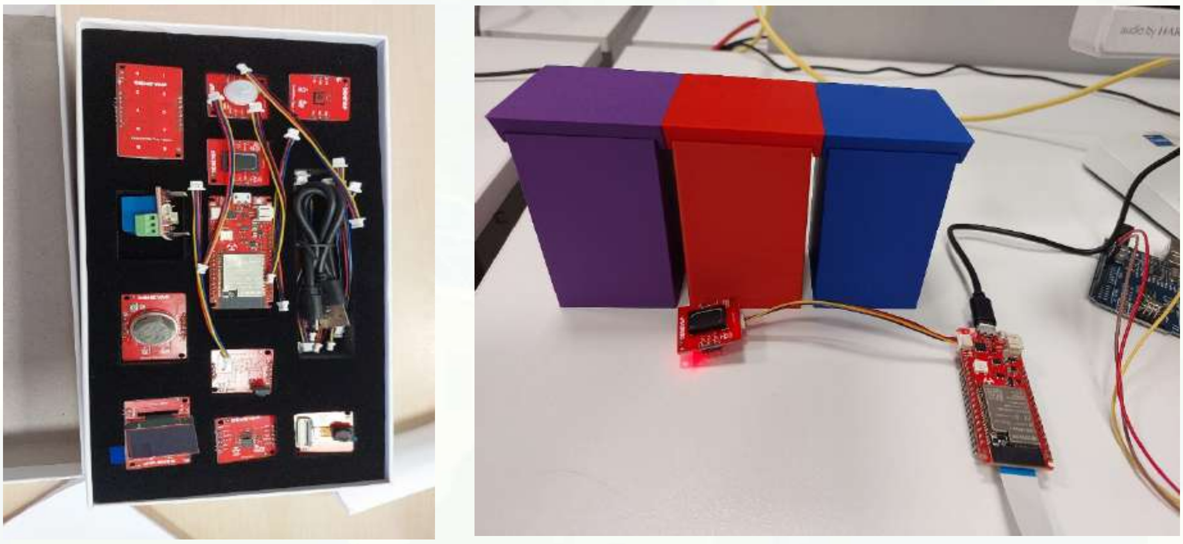

Figure 2. Integration of the Deneyap Board and Camera System onto the Prototype

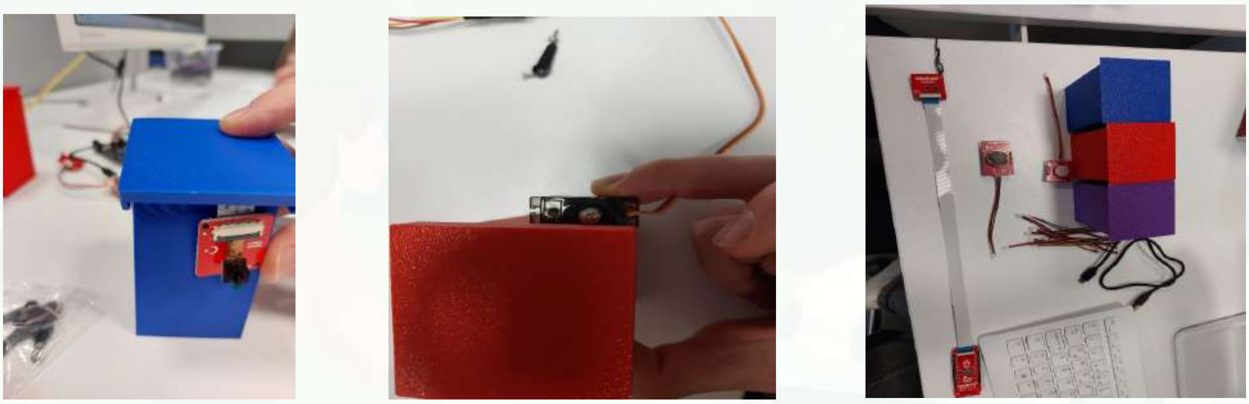

Figure 3. Testing of the System on the Prototype

To evaluate the system's performance, a series of trials were conducted using 30 waste samples labeled with distinct QR codes. Each test item represented a different material category—plastic, glass, or metal. The system successfully triggered only the cor responding bin lid for each scanned QR code, validating the accuracy of classification.

Main Results and Discussion

The experimental results demonstrated a **98% accuracy rate** in waste sorting operations. The remaining 2% error rate was attributed to factors such as automation latency and light reflection interfering with QR code detection.

The developed system is modular and adaptable, with the capability to be extended to other waste categories. It also holds future integration potential with advanced technologies such as artificial intelligence and wireless communication protocols. These findings indicate that the proposed solution is not only technically feasible but also scalable for deployment in residential, public, and industrial settings. Ultimately, it contributes meaningfully to sustainable waste management practices and the broader promotion of recycling awareness.

WASTE TYPE	SAMPLE QUANTITY	CORRECT SORTING(%)
PLASTIC	10	%98
METAL	10	%98
GLASS	10	%98

Table 1: System Performance Evaluation

Conclusion

The QR code recognition and automation-based intelligent waste sorting system developed in this study offers an innovative approach to optimizing recycling processes. By ensuring accurate classification of waste, the system effectively prevents contamination between waste streams and reduces the operational costs associated with municipal sorting efforts. Moreover, its accessible design facilitates the participation of individuals with disabilities in recycling activities, thereby promoting social inclusion and equity.

While the current system relies on QR code identification for sorting, future iterations could significantly benefit from the integration of machine learning-based image processing models. Such enhancement would enable direct and autonomous recognition of waste types without the need for pre-applied codes, further streamlining the sorting process and increasing system adaptability.

To enhance sustainability, powering the system with renewable energy sources such as solar panels could reduce its environmental footprint by minimizing energy consumption. Furthermore, embedding this solution within broader waste management policies can facilitate wide-scale adoption and operational coherence.

The modular and scalable nature of the system makes it suitable for deployment across diverse environments, including educational institutions, healthcare facilities, shopping centers, and industrial plants. Customized versions designed for high-volume waste management could address the needs of larger facilities and urban centers.

In conclusion, this research underscores the potential of combining automation and accessibility to advance sustainable waste management. The full integration of artificial intelligence represents a critical next step to achieving an intelligent, autonomous, and universally accessible waste sorting ecosystem. Future research should prioritize the development of AI-driven classification algorithms, coupled with real-time system monitoring and user interaction analytics, to optimize performance and foster widespread implementation. This approach promises to contribute not only to environmental sustainability but also to social inclusiveness, setting a benchmark for future smart city initiative.

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Resilient Cities and Sustainable Future: Youngsters Discuss Future of the Cities

The Importance of Disaster-Resilience on Post-Disaster Urban Planning in Non-Resilient Areas

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ABSTRACT

Earthquakes and urban disasters don't just break buildings, they expose how fragile our cities really are. The 2023 Kahramanmaraş quakes showed this in brutal detail: thousands died, buildings collapsed, and the economic toll was massive. All because of poor construction and planning. These disasters reveal deep flaws that take years to fix.

Here's the hard truth: we can't keep doing this. Every disaster proves we need to act fast. We need stronger buildings, fairer recovery plans, and smarter city designs, especially as climate change makes everything riskier. While we're learning to live with some risk, the patchwork safety standards across cities just aren't good enough. Türkiye's tragedy proves we'll never eliminate risk completely, but we can do much better. Right now, it's the poorest communities paying the price. If we don't change course now, it'll be too late

Key words: disaster resilience, earthquake recovery, urban reconstruction

Introduction

Disasters have always been a big deal for cities. They show us the weak spots of our buildings, governments, and even society's. But earthquakes? They're next-level scary especially in non-resilient urban areas. The damage isn't just physical; it messes up people's lives and local economies for years. Figuring out how to deal with these disasters is important. The February 6, 2023, Kahramanmaraş earthquakes in Türkiye exemplified this destructive potential, resulting in over thousands of fatalities, the collapse of buildings, and economic losses exceeding billions. This disaster not only underlined the consequences of inadequate seismic preparedness but also presented a critical opportunity to reconsider urban resilience in high-risk zones.

According to AFAD (2023a), two major earthquakes occurred on Monday, February 6, 2023. The first earthquake, with a magnitude of 7.7, struck at 04:17 local time with its epicenter in the Pazarcık district of Kahramanmaraş province. This was followed by a second earthquake of magnitude 7.6 at 13:24, centered in the Elbistan district of Kahramanmaraş. The earthquakes were followed by 7,184 aftershocks. The seismic events caused widespread building collapses and severe structural damage across eleven provinces: Kahramanmaraş, Hatay, Adıyaman, Malatya, Gaziantep, Diyarbakır, Şanlıurfa, Osmaniye, Elazığ, Kilis, and Adana, resulting in a total of 53,537 fatalities. AFAD (2023a) reported that in the aftermath of the earthquakes, a total of 14,740 search and rescue personnel were deployed to the region. These teams comprised members from AFAD, JAK, PAK, DİSAK, the Coast Guard, JÖAK, DAK, fire departments, Güven teams, the Ministry of National

Education, NGOs, and international search and rescue units. Additionally, field operations involved personnel from AFAD, the Gendarmerie, Police, UMKE (National Medical Rescue Teams), the Ministry of National Defense, ambulance teams, local security forces, and local support units, along with 5,396 volunteers. As of February 21, 2023, the total number of personnel operating in the affected areas reached 242,392 (AFAD, 2023a). (Aydin et al, 2024)

These seismic events in Türkiye have exposed profound structural deficiencies, revealing systemic non-compliance with established construction standards and seismic building codes. Post-disaster analyses show that these urban centers suffer not only immediate physical destruction but also continuing systemic failures that extremely compromise recovery directions and long-term rehabilitation efforts.

The second stream of thought is that improving the performance of natural resource systems requires an emphasis on institutions and property rights. A people-oriented approach which focuses on the resource user rather than on the resource itself is not a new idea; many have pointed out that 'resource management is people management'. However, tools and approaches for such people management are poorly developed and the importance of a social science resource management has not generally been recognized. (Berkes, F. et al)

Therefore, disaster resilience obviously connects risk management with sustainable development. The focus must shift from emergency response to proactive, long-term risk reduction. This transition is key to minimizing future disaster impacts.

Methodology

Context

This research is about the importance of urban planning on non-disaster resilient areas after the disaster occurs. In the light of this study, one could be able to find the reason why building and maintaining disaster resilience in urban areas before the disasters, especially earthquakes. This research was carried out comparatively in terms of disaster resilience. Specifying the Kahramanmaraş earthquake happened on February 6th, 2023, we collected the data from the sources of NGOs, search and rescue teams, and government recordings.

Sampling

The target population was the citizens of Türkiye. The vicinity for working and searching was the internet. In order to compare and contrast the non-disaster resilient cities of Türkiye with the resilient ones in the world, we searched for the publications collectively.

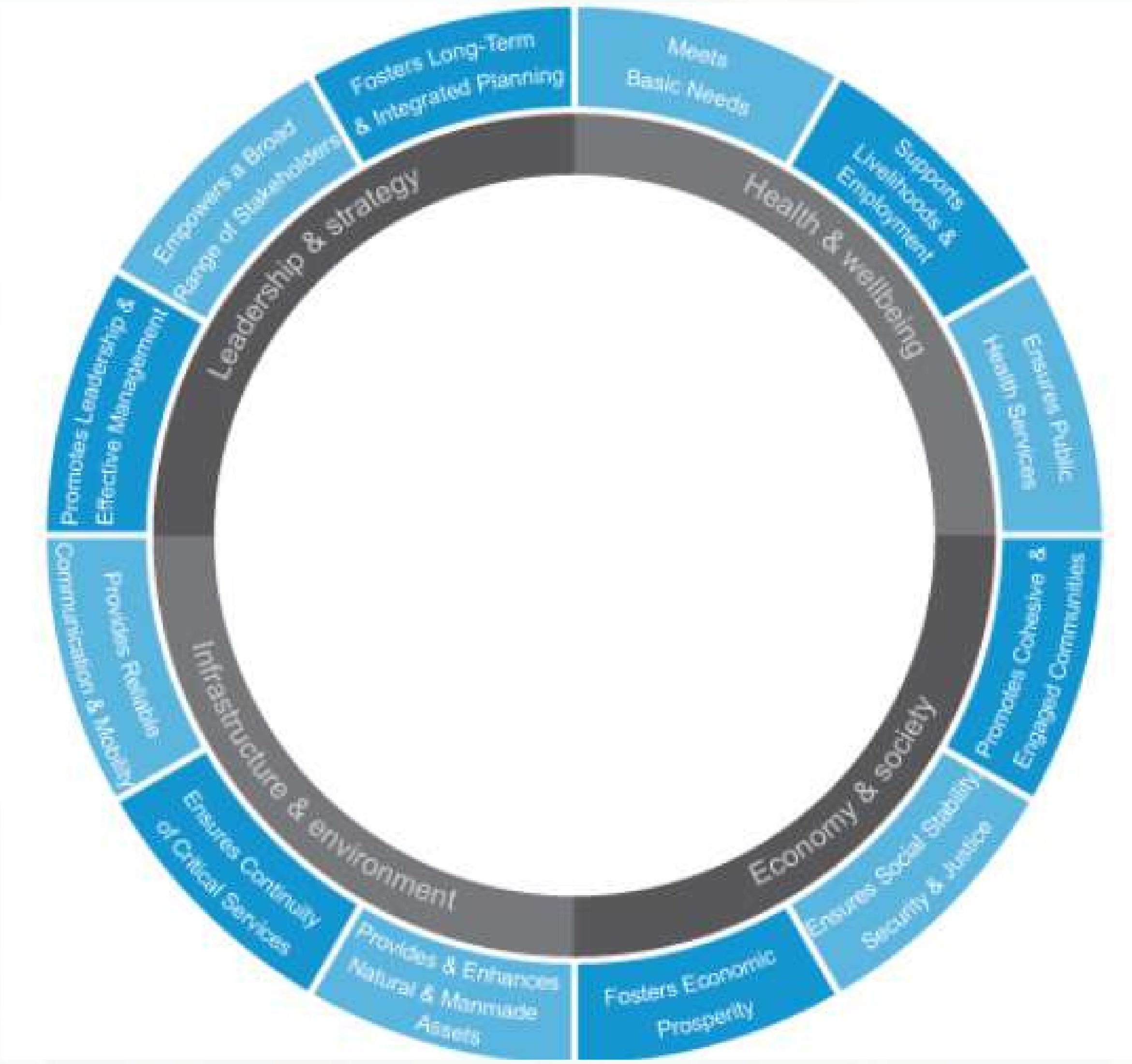
Data Collection

While collecting data, we drained the information from prejudgement controls, dived into deep research and came up with the real numbers and amounts of the devastating earthquake.;

Main Results and Discussion

The City Resilience Framework is a unique framework developed by Arup with support from the Rockefeller Foundation, based on extensive research in cities. It provides a lens to understand the complexity of cities and the drivers that contribute to their resilience. Looking at these drivers can help cities to assess the extent of their resilience, to identify critical areas of weakness, and to identify actions and programs to improve the city's resilience. (ARUP. 2014)

Figure 1



Resilience in individuals, institutions, and urban systems depends on key aspects: strategic foresight, adaptive reuse, load-bearing capacity, fail-safe networks, flexibility, inclusivity, and integration. Strategic foresight actors learn from past experiences to adapt their decisions and behaviors, making them more responsive to change. Adaptive reusing finds innovative ways to repurpose available means during crises.

Systems designed for resilience prioritize load-bearing capacity (ensuring failure is predictable and non-catastrophic), fail-safe networks (building spare capacity and diverse solutions), and flexibility (adapting strategies when faced with sudden challenges). For instance, cities might reorganize public transport for evacuations, while energy networks with redundant pathways can confront supply shocks.

Therefore, resilience is not just technical but also social. Inclusive governance makes certain that planning addresses the needs of the most vulnerable, nurturing shared ownership of solutions. Meanwhile, integrated approaches help different sectors work together instead of staying isolated. For example, cities are using multidisciplinary urban plans to address climate adaptation and disaster risks as one unified effort. Together, these strategies don't just help cities and their residents recover from disruptions, they set them up to grow stronger and thrive.

To present some quantitative data concerning the member organization and the work carried out in the region, it should be noted that 17,545 members declared their availability to support the efforts, while 8,944 members participated in damage assessment training. A total of 2,155 volunteer members engaged in fieldwork within the region. Volunteers were informed that contributing effectively required a minimum commitment of six days, and compliance with this duration was generally observed. Furthermore, depending on the scale of destruction in urban, rural, or operational zones, daily damage assessments varied, though each team evaluated an average of 30 structures per day. Based on this methodology, it can be estimated that members of the Chamber of Civil Engineers conducted structural damage assessments in approximately 200,000 buildings. (MO İstanbul, 2023)

Here is a table demonstrating damage frequencies and intensity measures city by city. (Pujol et al. 2024)

Table 1

Table 3. Damage frequencies and intensity measures.

City/district	Damage frequency (%)	PGA (g)	PGV (m/s)	$S_{d0.3}$ (m)	$S_{v0.3}$ (m/s)	$S_{a0.3}$ (g)	S_{d1} (m)	S_{v1} (m/s)	S_{a1} (g)
Ministry survey									
Altınözü, Hatay	26	0.53	0.54	0.04	0.74	1.57	0.18	1.12	0.72
Andırın, Kahramanmaraş	12	0.16	0.15	0.01	0.19	0.40	0.03	0.16	0.10
Antakya, Hatay	50	0.54	1.04	0.04	0.81	1.73	0.45	2.84	1.82
Arsuz, Hatay	7	1.34	0.65	0.07	1.37	2.93	0.21	1.31	0.84
Belen, Hatay	9	0.38	0.51	0.03	0.59	1.27	0.13	0.79	0.50
Ceceli, Kahramanmaraş	44	0.68	0.96	0.07	1.54	3.29	0.19	1.22	0.78
Defne, Hatay	40	1.37	1.70	0.16	3.30	7.05	0.55	3.43	2.20
Dörtyol, Hatay	7	0.25	0.40	0.02	0.33	0.71	0.16	1.02	0.66
Göksun, Kahramanmaraş	39	0.64	1.71	0.02	0.51	1.09	0.18	1.13	0.72
Hassa, Hatay	28	0.65	1.12	0.04	0.85	1.82	0.23	1.41	0.91
İskenderun, Hatay	14	0.13	0.28	0.01	0.16	0.34	0.09	0.54	0.34
Islahiye, Gaziantep	27	0.66	1.13	0.05	1.11	2.37	0.31	1.93	1.23
Kırıkhan, Hatay	34	0.73	1.20	0.05	1.07	2.28	0.31	1.92	1.23
Nizip, Gaziantep	4	0.17	0.13	0.01	0.18	0.39	0.07	0.45	0.29
Nurdağı, Gaziantep	50	0.60	1.09	0.05	1.03	2.21	0.48	3.01	1.93
Pazarcık, Kahramanmaraş	31	0.63	1.22	0.03	0.68	1.46	0.24	1.52	0.97
Samandağ, Hatay	38	0.22	0.79	0.02	0.35	0.74	0.22	1.40	0.90
Türkoğlu, Kahramanmaraş	28	0.46	0.56	0.04	0.87	1.85	0.16	1.02	0.65
ACI-133 survey									
Antakya, Hatay	26	0.99	1.33	0.06	1.29	2.75	0.35	2.20	1.41
Elbistan, Kahramanmaraş	22	0.40	0.93	0.03	0.57	1.21	0.21	1.29	0.83
Hassa, Hatay	32	0.59	1.29	0.04	0.75	1.60	0.23	1.45	0.93
Kahramanmaraş (central)	35	0.41	0.61	0.03	0.56	1.19	0.22	1.36	0.87
Kırıkhan, Hatay	17	0.75	0.86	0.05	1.07	2.29	0.19	1.21	0.77
Malatya (central)	25	0.45	0.35	0.02	0.46	0.98	0.14	0.86	0.55
Nurdağı, Gaziantep	38	0.60	1.09	0.05	1.03	2.21	0.48	3.01	1.93
Türkoğlu, Kahramanmaraş	19	0.68	0.96	0.07	1.54	3.29	0.19	1.22	0.78

PGA: peak ground acceleration; PGV: peak ground velocity; ACI: American Concrete Institute.

These repeated disasters make it clear: we need change and we need it now. To prevent future tragedies, we must strictly invest in resilient and decentralized infrastructure, ensure fair recovery efforts, and incorporate cultural heritage into urban planning. What we can't accept is the same destructive cycle where disasters strike, and only some communities recover.

With climate change accelerating and cities expanding, the lessons from Kahramanmaraş and other disaster-prone areas should push us to act. We have to build cities that can resist the growing threats of our time before it's too late. Many cities in Türkiye remain disaster-vulnerable due to poor planning.

Conclusion

The earthquake's devastation is tragic; however, it is a chance to rebuild smarter. Unlike older cities that struggle to upgrade outdated systems, we can now design these areas as smart cities from the ground up. We should avoid the usual costs and complications of renewing. The upfront investment may seem steep, but technologies like renewable energy grids, advanced waste management, and streamlined governance will pay off in the long run by cutting costs and conserving resources.

But it's not just about infrastructure. These improvements can also empower people by integrating education and job training programs, we can boost community engagement and literacy rates, creating a stronger, more skilled workforce. In the end, this approach doesn't just rebuild cities, it transforms them into more efficient, sustainable, and resilient places to live.

Here is an OECD report to indicate how to establish disaster resilience in urban areas with a table classified by sectors and purposes.

The table below shows sample aid activities and/or development objectives and potential eligibility and scoring for the DRR marker based on the decision process and eligibility criteria presented in the proposal. (*2-Principal; 1-Significant*) (Fabre C, et al. 2017

Table 2

Sector/ purpose	Short description of the aid activity and/or development objectives	Potential Score
General Environment Protection	Integrating disaster risk considerations in environmental law, regulation, policy, planning and programming.	2
Disaster Risk Reduction	Building disaster resilient communities by strengthening national systems for disaster risk management, with accompanying national and sub-national risk assessment.	2
Industry	Assessment of disaster risk in the development of the industrial sector, and corollary impacts of industrial development on disaster risk.	2
Multi-hazard response preparedness	Strengthening national weather forecasting and warning services and disaster risk analysis for building sustainable national capacity for disaster risk management.	2
Energy Generation and Supply	Retrofitting and upgrading smart grids to be resilient to modelled cyclonic wind and flood risk, and promoting continuous service delivery.	2
Other Multisector	Building a city's resilience to earthquakes by reinforcing public buildings to seismically safe standards, and developing city-level disaster preparedness plans and policies.	2
Water Supply and Sanitation	Mobilise networks of NGOs and communities to advocate in favour of a strengthened national water policy and law, which considers sustainable use of water resources, sanitation services, and disaster risk reduction to support vulnerable populations.	1
Education	Support to Ministry of Education for shaping the research agenda on education in conflict-affected states, developing guidelines on education and child protection and corresponding training to education practitioners, and developing disaster risk reduction (DRR) plans for the education sector.	1
Agriculture	Enhancing the resilience of smallholder producers to climate variability by improved management of watersheds, introducing or expanding soil management practices, and reducing vulnerability of crop storage facilities to hazards.	1

In the light of interpreting this table prepared by OECD, the proposed contributions can be outlined as such; The rebuilding plan isn't just about fixing what was destroyed, it's about making the region stronger, smarter, and more resilient than before. Instead of simply putting up new buildings, we're redesigning communities with disaster prevention in mind, making sure they stay true to their cultural roots while integrating earthquake-resistant infrastructure. Houses and utilities (like water, power, and internet) will be built to confront future quakes, and we will obtain faster disaster responses meeting emergency supply centers strategically. Rural areas will get eco-friendly upgrades, better transportation links, and special support for at-risk groups. Debris will be recycled responsibly, and reconstruction will use energy-efficient materials to cut waste and lower long-term costs. Factories and farms will be modernized with quake-proof upgrades, and job training programs will bring back skilled workers. Technology and private-sector partnerships will come up with better disaster-proof solutions.

Recovery isn't just physical, it's social as well. The plan improves healthcare, education, and local decision-making, working closely with NGOs, universities, and leaders to ensure everyone has a voice. By combining smart urban planning, cultural preservation, and sustainability, this strategy doesn't just rebuild, it sets a global example for disaster-prone regions. Once the results lower energy use, cost savings, they will prove that resilience is possible without losing identity or progress.

Acknowledgment : This article is dedicated to those who lost their lives in the earthquakes that occurred in Türkiye on February 6, 2023. Also, I would like to express my gratitude to my counselor and English teacher Gülşen Bardak.

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Green Cities For Sustainable Future: Urban Agriculture And Landscape Applications

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ABSTRACT

This study examines the contributions of urban agriculture and landscape application areas to urban ecology and reveals their roles in sustainable urban life.
Today, cities are complex ecosystems where living and non-living elements interact in a dynamic cycle. The projection that 65% of the world's population will live in urban areas by 2030 increases the importance of urban ecology. Urban green spaces and forest ecosystems constitute the fundamental pillars of sustainable urban life. These areas assume critical roles in improving air quality, carbon storage, and protection from climate change's negative effects. They function as ecological corridors by hosting biodiversity and support urban ecosystem sustainability.
Cities rapid expansion creates inevitable interaction with surrounding agricultural areas. In Turkey, the administrative integration of rural and urban areas through Metropolitan Municipality Law No. 6360 has deepened this interaction. Agricultural area reduction and green space decrease during urban expansion constitute a significant problem. In this context, urban agriculture emerges as an effective tool carrying ecological value and protecting urban ecology. Urban agricultural activities in private gardens, urban farms, and green spaces support biological diversity while contributing to air pollution reduction and temperature regulation. Ecologically, similar species coexistence increases system resilience, creating sustainable urban ecology.

Key words: Urban agriculture, landscape, ecology, biodiversity, sustainability

Introduction

Contemporary cities and metropolises confront serious challenges related to sustainability and resilience, shaped by rapid urbanization, climate change, environmental degradation, and socioeconomic inequalities. Addressing these interconnected and multifaceted issues requires strategic approaches that holistically integrate urban planning, infrastructure design, environmental conservation and social policy [1].

Urban agriculture constitutes a landuse model enabling enhancements in urban food security, reductions in air pollution, increases in urban biodiversity, improved waste management and the development of greener cities [2]. The Food and Agriculture Organization of the United Nations (FAO) defines urban agriculture as any agricultural production conducted within households or plots located in cities [3]. Whether agricultural activities carried out in periurban transition zones between rural and urban settlements fall under the scope of urban agriculture remains an unsettled issue in the literature (Figure 1: derived from a Google Earth screens-hot). While some scholars restrict urban agriculture to agricultural activities occurring strictly within urban boundaries, others extend the definition to include agricultural operations encompassing areas surrounding the city [4-5-6]. Furthermore, urban agriculture is not merely understood as productionoriented activity; it is regarded as a multidimensional structural domain where various forms of land tenure, social relations, and economic models intersect [7].

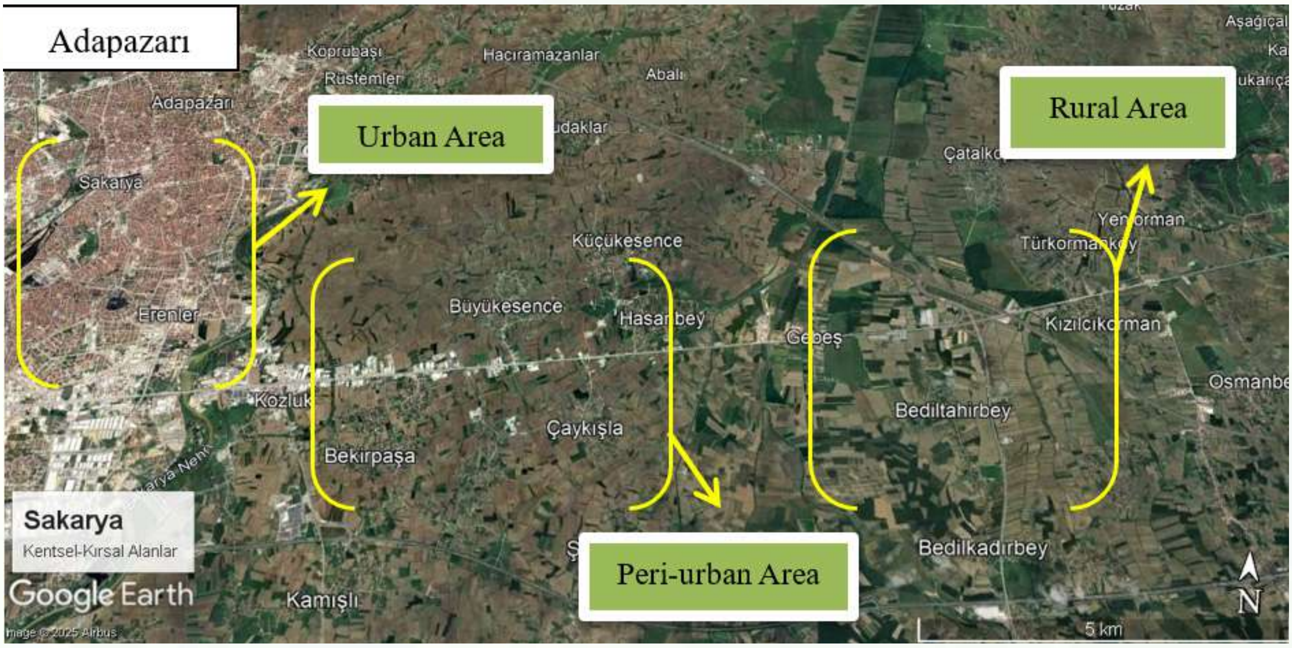

Figure 1. Boundaries of urban, rural, and peri-urban areas (Sakarya, Turkey)

Urban agriculture is not merely a production model; it is also increasingly associated with broader urban concepts such as climate change adaptation, social integration and spatial equity. In this context, urban agriculture is regarded as a strategic component of urban planning and governance processes. The planning of spaces designated for urban agriculture encompasses not only agricultural production but also landscape aesthetics, the functional transformation of vacant lands, water management and public health considerations.

The multidimensional nature of urban agricultures impact on the urban system underscores the need for a multidisciplinary approach. Research in this field cannot be confined to a single discipline; instead, it necessitates collaborative work across various academic and professional domains.

In order to fully harness the potential of urban agriculture, the establishment of legal frameworks, the allocation of suitable land, the development of sustainable financing models and capacity-building efforts based on education are essential. Particularly in growing cities, the protection and revitalization of agricultural land are critically important for enhancing the resilience of local food systems and developing climate-resilient urban structures.

The main objective of this study is to demonstrate that urban agriculture is not merely an alternative food production practice, but can be strategically utilized as a planning tool in line with sustainability and urban resilience goals. Within this framework, the environmental, social and economic dimensions of urban agriculture are examined in an integrated manner.

Urban Agriculture and Its Importance

With the expansion of cities, the intermingling of urban areas and adjacent agricultural lands has become inevitable. In Turkey, Law No. 6360 on Metropolitan Municipalities has enabled a shift in the urban administrative structure, allowing rural and urban areas to be governed under similar frameworks. As a result, it has become technically feasible to carry out agricultural practices within urban boundaries. At the same time, urban ecology influences agricultural areas just as agricultural zones affect urban biodiversity and ecological processes. For instance, even though the presence of natural and agricultural lands, cities continue to expand in size and this expansion adversely impacts both urban and peri-urban agriculture [8-9]. The leapfrog and fragmented patterns of urban sprawl encroach upon production-oriented rural lands, resulting in their use beyond their original functions. This process contributes to the degradation of the natural landscape in rural areas [10]. Consequently, rapid urban expansion cause to a significant reduction in green spaces [11]. Even though the increasing recognition of urban agriculture over time, particularly in developing countries, its effective integration into urban governance mechanisms remains insufficient [12-13]. It is estimated that by 2030, two-thirds of the world's population will reside in urban areas. This trend implies an increasing demand for urban land, which will be allocated according to the principles of highest and best use [4]. Accordingly, the value of land in urban areas is rising steadily. Ensuring sustainability in urban areas is often constrained by the pressures that current planning and land-use practices place on ecological systems. Successful sustainable urban development is a critical necessity to ensure that both the environment and society can maintain a balanced and healthy existence in the long term [14].

As cities grow rapidly, the agricultural activities and potential of rural areas surrounding cities become increasingly integrated with urban systems. In developed countries, various steps have been taken to preserve and enhance these agricultural lands. The policies that have emerged from such efforts have redefined agricultural practices in rural areas under the term "urban agriculture" [15].

Urban areas are responsible for more than 70% of global greenhouse gas emissions a figure that is projected to rise further. Moreover, the lack of effective waste management actions in many cities contributes to emissions of methane and chlorofluorocarbons. At this point, urban agriculture along with peri-urban agriculture and urban forestry-plays a role in mitigating the factors contributing to the global climate crisis and in fostering resilient cities [16]. In addition to its potential to alleviate the effects of the climate crisis, urban agriculture has historically functioned as a food security strategy during periods of economic hardship and natural disasters. Thus, it may be considered a strategic component in building resilient urban systems [17].

Urban agriculture can take different forms depending on spatial scale and is generally classified into three main categories. The first group consists of practices at the architectural scale, including small-scale individual initiatives such as balcony, indoor, rooftop gardening and vertical farming. The second group includes neighborhood-scale production models such as container gardening, regenerative landscape areas and community farms. The third group comprises city-scale agricultural activities, including allotment gardens, greenhouse cultivation, urban farms, guerrilla gardening and hobby gardens [18]. Additionally, animal based production activities, such as beekeeping, poultry farming are also considered part of urban agriculture [19].

Urban agriculture involves a multifaceted production model that includes vegetables, fruits, medicinal and aromatic plants, ornamental plants, mushrooms and various animal products. Moreover, it can be integrated with landscape plants to support both the aesthetic and ecological functions of the urban ecosystem [20]. The cultivated species are grown either collectively or on fragmented small sized plots [21].

The Impact of Urban Agriculture on Urban Life and Urban Landscape

The effects of various urban agriculture practices on the urban ecosystem differ based on their type and scale. Urban agriculture areas, which are often incorporated into urban green spaces, contribute to the urban landscape by introducing elements of green infrastructure, thereby supporting biodiversity [22]. In addition, the promotion of ecological diversity can extend beyond the designated cultivation areas and positively affect surrounding plots as well [23]. Studies have shown that urban agriculture practices characterized by high plant diversity can positively influence the diversity of invertebrate species [24]. Therefore, the abundance and variety of plant and animal species within and around urban agriculture sites should be taken into account in ecosystem related studies. Urban agriculture practices can also benefit the water cycle in urban ecology. Unlike impermeable concrete surfaces that prevent rainwater infiltration, cultivated soils allow water to reach the ground, thus contributing indirectly to groundwater recharge. Moreover, the collection and storage of rainwater for agricultural use is another important situation in supporting the urban hydrological cycle [25].

Table 1. Benefits of Urban Agriculture

Benefit Area	Provided Benefit
Food Security	Facilitates direct access to healthy and accessible food for the urban population [26].
Economic Contributions	Reduces household expenditure, generates income and promotes local employment [26-27].
Social Solidarity	Strengthens inter-communal solidarity and social inclusion through co-production spaces [27-28-29].
Environmental Benefits	Provides carbon sequestration, reduces heat island effect, contributes to stormwater management [27].
Education	Enhances environmental awareness and solidarity: facilitates intergenerational transfer of agricultural knowledge [30-31].
Public Healt	Promotes healthy eating habits; supports physical activity and mental health [29].
Biodiversity	Increases flora and fauna diversity in urban landscapes; provides habitat for pollinators and insects [29].
Disaster and Crisis Resilience	Increase community self-sufficiency in food crises and disaster situations.
Aesthetic and Landscape Contribution	Improves urban aesthetic perception by increasing green areas [17, 32].
Rural-Urban Integration	Ensures production-consumption balance between rural and urban systems [33].

Urban agriculture is considered a strategic tool in reducing urban poverty and ensuring food security for households [34]. The spatial disconnection of modern cities from food production has turned cities into settlements where access to affordable and healthy food has become increasingly difficult [35]. Here, urban agriculture allows city-dwellers to produce plant and animal based food locally, thereby reducing the environmental impacts and energy consumption associated with food transport by shortening the distance between production and consumption. Also, it contributes to public health by providing direct access to clean, reliable, and sustainable food. Consuming local products also reduces the ecological footprint and increases interest in farmers market and urban farms [10].

Urban agriculture offers alternative solutions to challenges brought about by urban life, thus holding significant potential with regards to achieving sustainable development goals [36]. The implementation of urban agriculture near city outskirts helps mitigate transportation related issues common in rural areas and supports the continuity of production. The dual urban-rural characteristics of peri-urban areas help prevent the loss of agricultural land caused by urban expansion, offering a clear advantage for sustainability [37].

On the other hand, the ecological impacts of agricultural activities carried out in peri-urban areas become more pronounced compared to those conducted within city centers. In this regard, reducing the urban heat island effect and increasing biodiversity are among the leading ecological contributions of such activities [36].

Green spaces stand out with their carbon sequestration capabilities. Plants used in landscape practices are known to support biodiversity and act as ecological corridors, thereby contributing to sustainability [38]. Urban agriculture, similar to the effects observed after the implementation of landscape designs, exerts positive influences on both people and nature. Urban green areas meet the publics need for open space, prevent uncontrolled urban sprawl and contribute to the aesthetic quality of cities. These spaces also serve as social gathering points, offering various societal functions [39]. Studies have shown a negative correlation between the lack of access to urban green spaces and factors such as mortality rates, heart rate, and incidents of violence, while attention span, mood and physical activity show a positive correlation [40]. From a landscape design perspective, urban agriculture opens the door to efficient use of natural resources, respect for cultural heritage, and the development of innovative design concepts within cities [41]. In addition, it is essential that urban agriculture be integrated harmoniously with the city's landscape and designed in alignment with the unique structural features of each city. In line with its significant contributions to the sustainable city concept, urban agriculture should be preserved and promoted as an integral part of urban landscapes.

However, urban agriculture also presents certain environmental disadvantage. Extreme use of pesticides and chemical fertilizers in urban farming practices can lead to the pollution of water resources. Another concern is the level of contamination of urban soils. To ensure the cleanliness of food produced in contaminated areas, it has been advocated that urban farming should be conducted at least 10 meters away from heavily trafficked roadways [42].

The Current State of Urban Agriculture in Turkey

With the enactment of Law No. 6360 on Metropolitan Municipalities in Turkey, many rural areas have been reclassified as urban neighborhoods. Consequently, numerous economic activities and public services previously conducted in rural regions have come under the jurisdiction of metropolitan municipalities. However, ambiguities within the scope of this law have led to an unclear definition of the duties, powers, and responsibilities of local governments in these newly reclassified areas.

Currently, there is no legal framework specifically regulating urban agriculture in Turkey. This absence constitutes a significant barrier to the development and dissemination of urban agriculture practices [43].

Examples of urban agriculture practices in Turkey are most frequently found in Istanbul. Among the prominent examples are the Yedikule Gardens, Kuzguncuk Garden, and Çengelköy Garden. In Ankara, the Atatürk Forest Farm represents a noteworthy example. Additionally to serving as a site for agricultural activities, Atatürk Forest Farm continues to operate with the aim of fostering and sustaining the rural–urban connection [44]. Overmore, various municipalities across Turkey have initiated and supported urban agriculture projects at the local level. Notable initiatives include the Melen Botanical Valley Project by Sakarya Metropolitan Municipality, the Urban Garden Project by Bursa Nilüfer Municipality, the Bağlar Community Gardens Project by Diyarbakır Metropolitan Municipality and the Durhasan Lavender Garden Project by İzmit Municipality. Additional significant contributions to the proliferation of urban agriculture practices include the Urban Gardens initiative by Eskişehir Odunpazarı Municipality, the Community Gardens project by Konya Selçuklu Municipality and the Rural-Urban Agriculture Support Programs led by Antalya Muratpaşa Municipality.

Conclusion

With new urbanization models, the spatial ambiguity of city boundaries necessitates a more in depth analysis of transition zones between rural and urban areas, which holds critical importance for urban planning [45].

Urban agriculture is not only an alternative form of food production but is also regarded as a strategic tool in the recreation of sustainable urban planning, environmental balance policies and social well-being. Increasing urbanization pressure, the shrinking of agricultural lands, and the deepening impacts of the climate crisis position urban agriculture as both a necessity and an opportunity. This study highlights the multifunctional nature of urban agriculture in its environmental, economic and social dimensions, while also revealing the implementation challenges and potential opportunities, particularly within the context of Turkey. Its benefits in ensuring food security, contributing to green infrastructure and creating disaster-resilient communities demonstrate that urban agriculture should be addressed with a more holistic approach in the cities of the future.

The development of urban agriculture in Turkey remains limited mainly result deficiencies in the legal framework, governance uncertainties and institutional capacity challenges related to implementation. Although Law No. 6360, which reclassified rural areas as neighborhoods, has created new opportunities in spatial governance, gaps in practice have weakened coordination between rural development and urban management. As observed in successful examples from Europe and Latin America, integrating urban agriculture into development policies both preserves the productivity of urban fringes and reduces the vulnerability of food systems. In developed countries, legal infrastructure regarding urban agriculture is regulated and collaboration between local governments and civil society organizations is evident.

Examples, such as the historical urban gardens in Istanbul Yedikule and Kuzguncuk and the Atatürk Forest Farm in Ankara demonstrate that urban agriculture practices with historical continuity can be revitalized. However, these examples need to be restructured around institutional support, spatial planning and social participation. Within this context, urban agriculture should be promoted not only as an environmental or economic practice but also as a sociocultural activity embedded in urban life.

Taking into account all of these, various strategic, administrative and structural recommendations need to be developed to integrate urban agriculture into sustainable urban policies in Turkey. These recommendations are considered beneficial for the country under the following headings:

1. The establishment of a legal framework is essential. The definition, scope and implementation principles of urban agriculture should be legally clarified and relevant municipalities should be given regulatory and incentivizing roles in this area.
2. Production-oriented green spaces should be included in urban zoning plans and urban agriculture areas should be integrated into planning processes.
3. Education programs and technical support units regarding urban agriculture practices should be established through collaboration among local governments, civil society organizations and universities.
4. Community-based urban agriculture practices should be expanded and cooperation with cooperatives should be fostered.
5. The effects of urban agriculture applications on carbon sequestration, biodiversity and the water cycle should be monitored and supported by scientific studies.
6. Strengthening rural-urban linkages is necessary. Production areas on the urban fringe should be integrated with urban consumption systems to support the rural-urban food chain. Through these means, safe and healthy access to food for the public should be ensured.

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Smart Cities and Digital Divide: A Social Equity Discussion

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ABSTRACT

This paper examines how smart city projects address the digital divide while integrating citizens into their systems. Smart city initiatives escalated with the significant adoption of Internet of Things (IoT), information and communication technologies (ICTs), and artificial intelligence (AI) in urban systems. Although these technologies are optimized as an innovative response to increasing urbanization, these solutions have both benefits and challenges to urban life, depending on their planning objectives and the societal structures. The purpose of the study is to put emphasis on the social inclusion of diverse groups in the context of the smart city projects. This study adopts a qualitative and exploratory research approach to understand the digital divide in smart cities. The data is collected through a literature review based on keyword research on the Scopus database, and it is supported by relevant academic literature to shape the conceptual framework. A thematic analysis was conducted on the digital divide in smart cities to explore the academic debates and gaps in the literature. Accordingly, smart cities have sociotechnical aspects, and their implementations raise questions about social justice concerns by considering the social differentiations within the urban fabrics, rather than depending only on technological implementation processes and business-oriented appraisals. In this sense, this study focuses on the digital divide issues in smart cities by limiting its scope to the social equity discussions.

Key words: smart cities, digital divide, social equity, sociotechnical perspective

Introduction

Smart cities are envisioned at the intersection of developing technologies and the urban fabric. Over time, the challenges and opportunities of smart cities have become prominent in environmental sustainability and governance discussions, moving beyond the focus on technological adaptation [14]. The concept of smart cities refers to the sociotechnical systems proposed as one of the responses to the rising demands of cities with the aim of enhancing life quality, especially to support intelligent urban development and sustainable socio-economic growth for the citizens [12]. The evolution of cities is mediated by digital infrastructures, and ICTs are embedded into the urban fabric as new modes of urban governance that rely on big data [6]. The term smart city appeared as an urban infrastructure system charged with enabling energy, transportation, housing, and communication provisions while responding to escalating urbanization and population growth, and is synonymously regarded as "digital city" or "intelligent city" [3]. For instance, the "green city" is another concept that overlaps with the notion of smart cities in supporting economic processes and managing environmental resources [5]. Citizens, governments, and private companies are three stakeholders of social infrastructure in the smart cities. Accordingly, human capital appears as one of the crucial components of smart cities, since urban fabric comprises a diverse range of individuals from various socio-demographic backgrounds, and citizens are the end-users of the introduced smart technologies [12].

Social Equity in Smart Cities

The interconnected sociotechnical structure of the smart city design creates challenges for social equity in implementing and developing services to users [9]. Social equity is defined as a key factor for development in smart cities; further related policies are significant in terms of being a bridge between the technological and economic gap in the urban demographic relations. Accordingly, the term digital gap refers to the difference between who can afford technologies and who cannot afford them among citizens [5]. In relation to this, the concept of the “digital divide” pertains to societal differences in access to and knowledge of technology among various social groups. These potential digital gaps within societies can be addressed through adequate digital infrastructure and effective policy implementations in smart city initiatives [1]. Especially concentrating benefits around the smart city implementations, such as advanced infrastructure services and providing sociotechnical solutions in specific areas while excluding others, brings ‘digital marginalization’ concerns [3].
Furthermore, concerns over reproduction of social inequalities during the transition to a smart society increased with smart cities through ‘the smartness-induced inaccess’ to services, since the integration of ICT-based smart systems is celebrated in the governmental agenda for optimizing resource allocation and public service provisions [15]. Also, private companies, government bodies, and citizens might dissociate according to their different group interests; further, each smart city projects differ from others in accordance with their unique target groups [9]. In other words, social concerns vary depending on the idiosyncratic social dynamics. It is pointed out that limited dissemination of service, specifically the internet, could bring a “digital divide” while hindering the collective achievement of mass smart information services [12]. To detail, Nam and Pardo point out that the digital divide has location context to dissociate advantageous and disadvantageous groups depending on the neighborhood-specific accessibility and usability of the digital infrastructures and other services [11]. It is suggested that smart cities contribute to the reproduction of urban inequities. Similarly, their study with youth in Philadelphia proves that wealthy neighborhoods and their new economy become ‘smart’ while other parts of the cities are outcasted by digital investments and technology-driven urban change [8].

Mitigating the Digital Divide for the Future of Cities

The deployment of institutionally connected smart technologies in smart cities would bring several problems, not solely the technological challenges, but also the organizational challenges for the policymakers and other related stakeholders [9]. The digital divide is one of the challenges of smart city implementations among developing countries. Concomitantly, every citizen deserves to be equally treated in quality access to ICT, reaching available telecommunication services and the information and knowledge, regardless of their race, gender, income, and social group positions [5]. It is claimed that the digital divide appears as a significant notion for enacting accessible and inclusive city planning for everyone, and they put emphasis on the digital literacy and digital accessibility of vulnerable groups [12]. Their argument focuses on the prominent role of private-public partnerships, as service providers, in transforming social dynamics of urban places into digitally-inclusive places. Ahvenniemi and her colleagues suggest a rather holistic viewpoint for smart city implementations to consider environmental sustainability, societal wellbeing, and financial sustainability in accordance with the technological integrity [2].
Moreover, Caragliu and Del Bo conduct an empirical analysis on European cities, they analyze whether there is a relation between urban smartness and digital divide, and they state that the enhancing role of smart cities and the digital divide issue, which is not often referred to in the literature on European smart cities [4]. Their findings demonstrate that medium-upper level smartness has a negative effect on the digital divide,

whereas higher level smartness is not associated with inequalities. Therefore, they conclude that ICTs actually have the potential to bring democratic planning if smart technologies are used efficiently in future policy implementations. The concept of digital divide needs to be extended and re-conceptualized from individual level access to public and community-based organizations to fully understand who owns and manages 'big data' in a comprehensive way [10]. Moreover, smart city innovations need to embrace diverse social groups and maintain long-term legitimacy and sustainability planning through social engagements. Similarly, their point demonstrates that the digital divide emerges in relation to digital society, and it can be mitigated through policy directions since these disparities within society arise and revolve in accordance with the development of new technologies [13].

Methodology

During the paper selection process, a literature review is conducted through keyword research on the Scopus database to gather relevant articles. This study adopts a qualitative and exploratory research approach to understand the digital divide in smart cities. The data is collected through a literature review based on keyword research on the Scopus database, and it is supported by relevant academic literature to shape the conceptual framework. A thematic analysis was conducted on the digital divide in smart cities to explore the academic debates and gaps in the literature. The research question, "In what ways do smart city implementations mitigate the digital divide for social equity?" is defined to guide literature review and keyword selection within the sociotechnical imaginaries framework. Research topics are reduced to social sciences publications in the English language. Articles are selected from query results based on the thematic keywords searches, such as ("smart cit*" AND "digital divide"), by prioritizing their relevance to the study.

Main Results and Discussion

Especially, sociotechnical shifts have been expanding to various spheres of life with different applications around the globe. Herewith, diverse implementations in cities indicate the need for attention on both sociotechnical and environmental aspects of these technological shifts. Since sustainability and life quality have to be holistically considered through navigating the societal consensus in order to attain the effectiveness and efficient design of the smart solutions. Thinking about the smart city implementations brings discussions on improving the life quality of their audiences, whether implementations reach the whole society or partially. Social, in other words, soft infrastructure is an indispensable part of the smart cities, considering the intellectual capital and social capital, these components make smart cities a learning city and a knowledge city for enhancing local knowledge. Otherwise, they overlook the fact that people interpret technological developments in accordance with their backgrounds regarding specific sociocultural, political, and spatial locations. In fact, integration of the various groups regarding both expert and non-expert users into the sociotechnical city life matters for the social equity objectives for everyday life practices. Since a holistic viewpoint not only considers the three main stakeholders, referring to governments, companies, and citizens, but also the various social groups that citizens belong to, based on their different positions in their societies. The digital divide has to be accounted for by referring to its impact on the public life of citizens to participate in urban activities. Smart city initiatives have to implement policies that address the various socio-demographic groups and needs of citizens for an effective and equitable future in accordance with the project objectives.

Conclusion

The objective of this study is to acknowledge human infrastructure within smart city discussions. Smart cities appear as one of the sociotechnical implementations in order to support communities and their development in urban settings. The notion of smart cities brings the social, environmental, and technological dimensions together into the discussion. This paper intends to gather information about the future of smart cities while emphasizing the digital divide in smart cities to recognize various citizen groups and their conditions in being integrated into the new urban systems. Through this approach, smart cities are envisioned with their influence on the societal sphere, while academic literature mainly considers the technological innovations and innovative implementations. In a nutshell, this study aimed to provide a focus on the sociotechnical aspect of smart cities to highlight the significance of social equity for socially inclusive smart urbanism. Since smart city projects rely on the collective dynamics of several stakeholders. Citizen groups are diverse based on their social backgrounds and in-group relations, which are shaped by social, economic, cultural, gender-based, and disability factors. In other words, the group dynamics of citizens should be contemplated within smart city projects, such as socioeconomic status differences in access and digital literacy levels in technology usage. This paper has provided some initial points to the digital divide discussions in smart cities, but wider, in-depth studies are required to examine the topic in academic literature.

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Children, Youth and the City in Focus of Cultural Sustainability

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ABSTRACT

Cultural sustainability is of great importance in terms of education policies and youth strategies as an approach that aims to transfer social, cultural and historical accumulations to future generations. This study examines the opportunities offered for children and young people with a focus on cultural sustainability. The aim of the research is to evaluate various application areas such as cultural heritage education curriculum contents, artistic activities, digital cultural platforms, and national and local government-supported programs. The data obtained as a result of the literature review was conveyed with qualitative methods. The findings show that cultural sustainability requires not only the protection of cultural values, but also the transfer of these values to young generations in meaningful and participatory ways. In addition, it was concluded that cultural opportunities play an important role in terms of the development of social belonging and creative expression skills, and intercultural communication. The study provides guidance for politicians and educators by suggesting inclusive and innovative strategies in educational, social and digital areas to strengthen cultural sustainability.

Keywords: Cultural sustainability, child, youth, city, education

Introduction

With the impact of digitalisation, social transformations have accelerated globally. In such contexts, the preservation of cultural values and their transmission between generations has become more critical than ever. Especially underthe influence of dynamics such as digitalisation, urbanisation and globalisation, the risk of weakening local cultures has made cultural sustainability an important topic within the sustainable development agenda. Although culture is not directly listed as a goal within the United Nations 2030 Sustainable Development Goals (SGDs), it is considered a fundamental factor in achieving all goals.

In this regard, cultural sustainability is not only about preserving the past; it also means the ability to reproduce cultural heritage within the conditions of today and to transmit it particularly to children and younger generations. Young people play a critical role as both carriers of cultural diversity and as actors who will shape the society of the future. Therefore, the cultural opportunities provided to children and youth are significant indicators of the effectiveness of sustainable cultural policies. The effects of global digitalisation and urbanisation on cultural heritage have been previously emphasised within the context of sustainable development goals (UNESCO, 2019).

In this paper, the scope, quality, and accessibility of cultural opportunities provided to children, youth, and within the context of cities are examined, and their function in terms of cultural sustainability is evaluated. Furthermore, conclusions are drawn based on the roles of different institutions (education, local governments, civil society, etc.) and examples of implementation in this process.

Cultural Sustainability

In the 21st century, sustainability is the promise of social development and transformation towards an equitable and enriched world for future generations, ensuring the preservation of both the natural environment and cultural achievements (Dyllick & Hockerts, 2002). Cultural sustainability refers to the preservation of a society's cultural values, language, traditions, lifestyles, and identity over time and their transmission to future generations. The survival of cultural heritage, the protection of social diversity, and the continuity of culture by adapting to changing conditions are essential.

The Criteria for the Implementation of the Convention Concerning the Protection of the World Cultural and Natural Heritage were listed at the UNESCO meeting held in 2005, and management plans for World Heritage sites were mandated. In 2008, the Implementation Brochure for World Heritage Site Management Plans was prepared to outline and explain the necessary elements for management planning (Ringbeck).

In cultural sustainability, the aim is to protect, sustain, and renew culture, ensuring its transmission from generation to generation. Cultural sustainability is of great importance in fostering a sense of identity and belonging, strengthening social cohesion and solidarity, nurturing creativity and innovation, and developing long-term and socially sensitive perspectives in development policies. Sustainable cities and communities, quality education, peace, justice, and strong institutions are included within the scope of the United Nations 2030 Sustainable Development Goals, and cultural sustainability is thus also targeted within this framework.

Children

In the United Nations Convention on the Rights of the Child, every individual up to the age of 18 is defined as a child. This age serves as a universal reference point for ensuring the protection, development, education, and rights of children. A child is also a developmental, social, and cultural being. Biologically, a child is growing; psychologically, they are developing cognitive, emotional, and social skills; and socially, they gain meaning through interactions with their environment. Therefore, childhood is a critical stage in which an individual forms their fundamental values, identity, and perception of the world.

In a cultural context, a child is seen as the bearer of a society's values, traditions, and sustainability. From this perspective, a child is not only a being to be protected but also a key actor in social change and sustainable development.

Children learn the language, belief systems, traditions, and lifestyles of their society through experience. By transmitting these values across generations and reinterpreting them over time, they contribute to processes of cultural change. In this sense, children are not only individuals who need protection but also main actors in ensuring cultural sustainability. The cultural, educational, and artistic opportunities offered to children not only support their identity development but also ensure the cultural continuity and diversity of society. Curriculum contents on cultural heritage education, artistic activities, programmes supported by national and local governments, and digital cultural platforms are among the efforts aimed at cultural sustainability for children.

Youth

Youth refers to the developmental period between childhood and adulthood, during which individuals seek their identity, develop values, learn social roles, and gain independence. According to the United Nations, youth encompasses the age group of 15-24; however, these boundaries may vary depending on cultural, social, and institutional contexts. In Türkiye, TÜİK (Turkish Statistical Institute) and many official institutions define the youth population as those between 15 and 24 years old.

Youth is not merely a biological transition process but also a stage where individuals develop socially, emotionally, culturally, and cognitively, becoming active in areas such as education, employment, social participation, and cultural identity construction. In this context, young people represent a group that plays an important role in the dynamics of societal change and transformation, being both open to innovation and bearers of sustainability.

As carriers and transformers of cultural heritage, young people are at the heart of the sustainable development goals. In this regard, ensuring cultural sustainability requires the active participation of young individuals in recognising, preserving, transforming, and reproducing local values using the opportunities of the digital age.

Furthermore, with their potential for innovative thinking, entrepreneurship, and creating social impact, young people are important actors in preserving the vibrancy of culture and strengthening its intergenerational transmission. The opportunities provided to youth are regarded not only as a means for individual development but also as elements of cultural continuity and social solidarity.

City

A city is more than just a settlement with a high population density; it is a complex living space characterised by concentrated economic, social, cultural, and political activities, increased interactions among individuals, advanced infrastructure and services, and a historical and spatial identity. At the same time, cities are dynamic structures at the centre of sustainable development, cultural diversity, innovation, and social transformation processes. In this respect, cities play a decisive role in individuals' identity construction and in fostering a sense of social belonging.

Cities are not merely physical settlement areas but also dynamic living spaces where cultural accumulation is transmitted, social interactions are intensified, and opportunities for multidimensional individual development are offered. Particularly for children and young people, cities serve as learning environments where social and cultural experiences are gained, a sense of belonging and identity is developed, and educational, artistic, and innovative opportunities are provided.

In the context of cultural sustainability, cities play an important role as environments that allow for the preservation and intergenerational transmission of local values, while also enabling new generations to engage with these values and develop their creative potential. In this way, cities represent multilayered cultural ecosystems for children and youth, carrying the heritage of the past while shaping the possibilities of the future.

Education

Education is a systematic process aimed at enabling individuals to acquire knowledge, skills, values, and attitudes, and to promote both social and individual development. This process is not limited to the transmission of academic knowledge; it also functions as a means for individuals to adopt social roles, recognize their cultural identities, and achieve multidimensional growth. Education is a fundamental social institution that enhances individuals' intellectual capacities by strengthening their critical thinking, problem-solving, and decision-making skills.

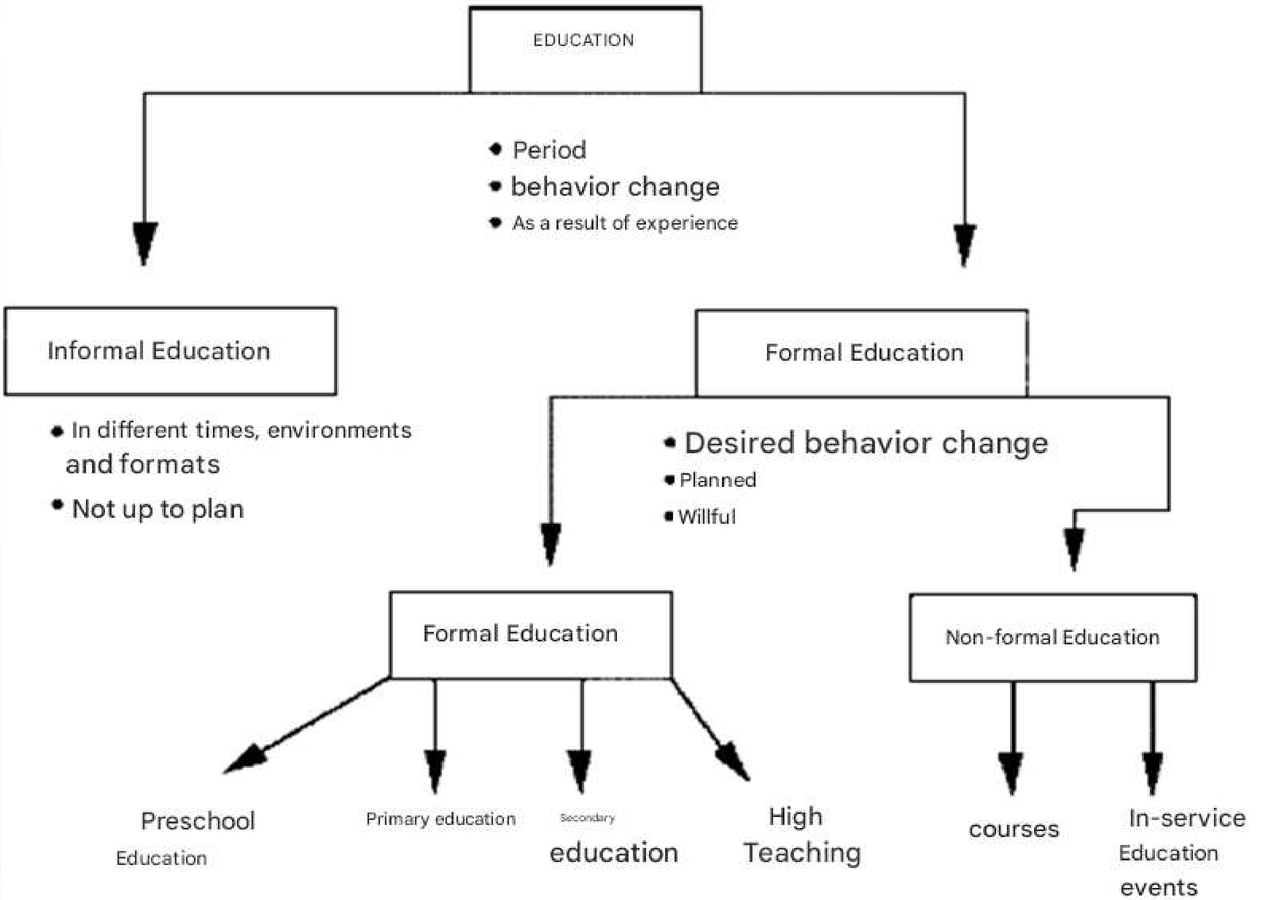

Figure 1: Types of Education

Cultural sustainability is ensured through both formal and informal education. Every human interaction represents an opportunity for informal cultural exchange. Through formal and non-formal education institutions, the transmission of cultural heritage is carried out in a planned and structured manner.

Education plays a central role in the preservation, transmission, and reproduction of cultural heritage. The transfer of cultural values to new generations, the recognition of diverse cultural identities, and the promotion of mutual respect are supported and encouraged through education. In this context, education fulfills key functions such as fostering awareness of cultural diversity, strengthening cultural belonging, and sustaining local knowledge systems. At the same time, equipping individuals with global citizenship awareness and cultivating openness to intercultural interaction increases the importance of education in terms of cultural sustainability.

Especially for children and young people, the educational opportunities provided enable them to recognize their cultural identities and develop sensitivity toward their cultural environments. Educational institutions should not be seen solely as structures that transmit knowledge, but also as social environments where cultural values are kept alive, questioned, and reproduced. In this regard, education is not only a means for individual development but also a tool for ensuring the long-term cultural continuity of societies.

Key Findings

Youth and sports centers, social development centers, and public education centers established by national and local government bodies have a significant impact on the sustainability of cultural activities. Practices such as culture and arts workshops, digital cultural content, local storytelling workshops, mobile culture vehicles, conferences, folk dance courses, museum visits, and youth camps contribute to the development of cultural belonging among children and young people. To ensure the sustainability of these programs, some companies have also been established, further contributing to increased intercultural communication. The role of local governments in cultural activities is also discussed in Göker's (2022) study. The types of cultural sustainability activities have different areas of impact depending on the target group.

Type of Activity	Target Group	Impact Area
Culture and arts workshops	Ages 12-18	Creativity, participation
Digital cultural content	Ages 15-25	Access to information, diversity
Local storytelling workshops	Ages 10-16	Cultural transmission, belonging
Mobile culture vehicles	Rural areas	Accessibility, equal opportunity

Table 1. Types of Cultural Sustainability Activities and Their Impact Areas

Social Development Centers (SGM) are specially operated by local governments with the approval of the Ministry of National Education. The SGM model stands out particularly in the case of Sakarya Metropolitan Municipality. Sakarya SGM operates in the districts of Adapazarı (central), Akyazı, Geyve, Sapanca, and Karasu. Since 2009, Family and Child Services, Services for People with Disabilities, and other social support units have been united under one umbrella. Within this scope, supportive programs such as children's clubs, family education programs, special courses for individuals with disabilities, and women's development academies are provided.

Special social activity and development centers approved by the Ministry of National Education offer programs tailored to the interests, talents, and academic development of middle school students. These centers operate under the status of private educational institutions and offer interface activities and workshops in areas such as drama, art, chess, foreign languages, speed reading, and music. Kadıköy Municipality's Social Service Centers conduct programs in areas such as personal development, vocational training, and hobby courses. Similar centers are operational in many other provinces and districts. Announcements about these programs and activities are commonly shared via social media platforms (Instagram, Facebook). Key areas of activity in social development centers include workshops for children—such as coding, speed reading, chess, and creative drama—as well as social support programs, academic assistance, guidance services, and vocational training for women and individuals with disabilities (e.g., hobby and occupational courses, effective communication).

In Turkey, Public Education Centers (HEM) play a vital role as one of the cornerstones of cultural sustainability and lifelong learning policies. These institutions support lifelong learning and provide opportunities for individuals to develop their knowledge, skills, and cultural identities. Courses opened for children and youth hold strategic importance for cultural transmission. Operating under the Ministry of National Education, these institutions offer educational services in various fields to individuals outside the formal education system to help them develop their knowledge, skills, and competencies. The courses provided at HEM include personal development, vocational and technical training, socio-cultural activities, as well as art and sports.

These programs aim to enhance employability, facilitate participation in socio-economic life, and contribute to the preservation of cultural values. Programs offered specifically for women, youth, individuals with disabilities, unemployed persons, and disadvantaged groups are of great importance in terms of social inclusion and community cohesion. Practical training courses are organized in a wide range of fields such as wood painting, sewing and embroidery, computer literacy, foreign languages, handicrafts, food technologies, agriculture, and livestock. Additionally, the rise in online courses following the pandemic has been notable. Through collaborations with local governments, NGOs, and the private sector, course content is continuously updated and adapted to regional needs. Public Education Centers are multi-functional institutions that contribute not only to individual development but also to societal progress and hold an important place in Turkey's educational and cultural policies.

Cultural Courses for Children and Youth:

- Values education
- Correct and effective use of the Turkish language
- Traditional handicrafts (e.g., marbling, illumination, kilim weaving)
- Turkish folk dances
- Training in traditional musical instruments (e.g., bağlama, ney, kaval)
- Drama and folk theatre
- Regional culinary culture studies

These courses enable children and young people to develop their sense of identity, strengthen their cultural bonds, and help preserve traditional knowledge.

Sample Implementations
Konya Public Education Center (HEM): Organizes educational programs that promote Mevlevi music and the tradition of the Sema ceremony.

Mardin Public Education Center: Offers courses in local clothing design and Assyrian handicrafts, contributing both culturally and economically.

Artvin Public Education Center: Raises cultural awareness among children through folk dance courses based on Laz and Georgian cultures.

Young people participating in HEM courses report that these educational experiences strengthen their cultural identity, increase their interest in learning, and enhance their curiosity about different cultures through new friendships.

2. Expanding Cultural Heritage Education Beyond School-Based Programs
To ensure that cultural heritage education and transmission are not limited to school-based programs, activities and projects have been developed to encourage active participation from families and communities. A comprehensive analysis of cultural sustainability education strategies was conducted by Erten (2021).

Non-formal education institutions—such as public education centers, private courses, vocational training centers, open primary and high schools, apprenticeship training centers, and in-service training—are as effective as formal educational institutions in preserving and transmitting cultural elements and heritage.

3. Regional Access and the Role of Digital Education
Formal education is conducted nationwide according to a standardized curriculum; therefore, regional disparities in content do not exist. However, access to non-formal education institutions varies significantly by region. Although regional inequalities in access to cultural activities and projects are notable, the expansion of digital education has helped to maintain cultural sustainability.

Children and young people living in large urban areas have greater access to cultural events, while those in rural areas face limited opportunities. To promote cultural sustainability, the production of digital content should be increased, and incentives such as funding, transportation support, and awards should be provided to encourage participation in events and projects.

The preservation and intergenerational transmission of cultural heritage is carried out primarily through formal education institutions. These institutions already have the planning, structure, and resources necessary for sustainability. Formal education institutions in Turkey contribute meaningfully to cultural sustainability.

Formal Education Institutions:

Preschool Education Institutions

Independent kindergartens

Kindergarten classes (affiliated with primary schools)

Practice kindergartens (affiliated with relevant university departments)

Primary Education Institutions

Primary schools (Grades 1–4)

Middle schools (Grades 5–8)

Science-oriented middle schools

Imam Hatip middle schools

Foreign language-oriented middle schools

Secondary Education Institutions (High Schools)

Anatolian High Schools

Science High Schools

Social Sciences High Schools

Vocational and Technical Anatolian High Schools

Health Vocational High Schools

Information Technology High Schools

Tourism and Hospitality High Schools

Imam Hatip High Schools

Fine Arts High Schools

Sports High Schools

Higher Education Institutions

Public universities

Private universities

Vocational schools of higher education

Open education faculties (considered formal as they are under the Council of Higher Education)

Other Formal Institutions Affiliated with the Ministry of National Education (MoNE)

Teacher guesthouses and training hotels (as part of vocational education)

Science and Art Centers (BİLSEM)

Guidance and Research Centers (RAM)

Special public schools for students with visual, hearing, or learning disabilities

4. Digital Cultural Content and Regional Inequality
Digital cultural content (such as art, documentaries, and local stories) is increasingly consumed by young people. While universal cultural elements are expanding within digital media, local cultural elements must also be increasingly represented. The growing demand for digital content highlights the need to eliminate regional inequalities—an issue also emphasized by Keleş and Bilgin (2018).

In Turkey, non-formal education institutions contribute to cultural sustainability by ensuring the intergenerational transmission of local cultural elements. They aim to provide individuals—especially those outside the formal education system—with a lifelong learning approach to acquire diverse knowledge, skills, and competencies.

Examples of Non-formal Education Institutions:

Public Education Centers (HEM)

Operate in every province and district of Turkey

Offer vocational, artistic, and cultural courses for individuals of all ages

Sample courses: handicrafts, computer literacy, language courses, hairdressing, sewing & embroidery, personal development

Vocational Education Centers (MESEM)

Prepare individuals for professional life

Provide apprenticeship, journeyman, and mastership certifications

Combine education with workplace training

Open Education Schools

Offer distance learning opportunities for individuals who cannot attend formal schooling

Types:

Open Primary School

Open Middle School

Open High School

Vocational Open High School

Maturation Institutes

Aim to preserve and teach traditional Turkish handicrafts

Provide training in fashion design, clothing production, embroidery, etc.

Municipality-Sponsored Vocational Training Programs

(e.g., İSMEK – Istanbul, SAMEK – Sakarya, BUSMEK – Bursa, KOMEK – Konya)

Common in major cities

Support social, cultural, and vocational development of the public

Social Development Centers (SGM)

Offer education and social support for groups such as families, women, children, youth, and individuals with disabilities

Typically operated by municipalities or NGOs

Private Courses and Study Centers

Private enterprises approved by the Ministry of National Education

Provide preparatory courses for national exams like LGS, YKS, KPSS, or vocational skills training

Turkish Employment Agency (İŞKUR) Training Programs

Provide short-term vocational and entrepreneurship training based on labor market needs

May also offer stipends or participation allowances to attendees

University Continuing Education Centers (SEM)

Operate within universities

Offer certificate programs, distance learning courses, and other flexible educational options

5. Role of Civil Society Organizations (CSOs)
Projects carried out by civil society organizations in the field of cultural sustainability play a crucial role in reaching disadvantaged groups. However, the impact of these projects is often limited to the duration of the project itself.

Conclusion

Ensuring cultural sustainability means not only preserving the past but also keeping cultural diversity alive and carrying it into the future. Children and young people are critically important as both transmitters and transformers in this process. In this context, the diversity, inclusiveness, and sustainability of the cultural opportunities offered to them are decisive for the success of cultural sustainability. Raising family awareness, providing economic support, and increasing incentives will be effective in maintaining cultural sustainability.

Social Development Centers and Public Education Centers are vital platforms for children and youth in terms of cultural sustainability. It is recommended to expand these centers, increase the production of content rooted in local culture, and support them with digitally enriched materials. Moreover, cultural courses should be delivered not only through transmission-based approaches but also with creative and participatory methods (e.g., project-based learning, drama-assisted education), which will enhance their effectiveness for sustainability.

To ensure regional balance in access to cultural opportunities, the production of digital cultural content should be increased, and mobile culture and art units (such as mobile libraries and traveling theaters) should be expanded in rural areas. Interdisciplinary programs that incorporate local cultural elements into school curricula should be enriched with events and models that involve families and communities in the educational process. Local governments should move beyond temporary events and institutionalize cultural activities within sustainable cultural policy frameworks. The production of local cultural content should be promoted on digital platforms, and creative spaces should be created where young people can participate as producers (e.g., digital storytelling workshops). To increase the impact of civil society in cultural sustainability efforts, collaborative models should be encouraged and successful practices and projects should be supported.

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AI-Supported Smart Irrigation Systems Against Graywater Microplastics

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Abstract
This study explores the increasing problem of microplastic pollution in graywater, which makes up a major part of household wastewater excluding toilet waste. Graywater, produced from sources like laundry, kitchen sinks, and showers, often contains high amounts of microplastics due to the washing of synthetic fabrics. As global water shortages become more serious, reusing graywater is seen as a sustainable option. However, without proper treatment, it can create serious risks for both the environment and human health. Microplastics can build up in the soil, be absorbed by crops, enter the food chain, and damage ecosystems and people.To prevent these problems, this paper introduces an AI-based smart irrigation system that includes real-time microplastic sensors. These sensors continuously monitor microplastic levels in irrigation pipes. If the amount exceeds the reference range, the system automatically stops the water and redirects it to a storage tank for non-agricultural use. This ensures that polluted water does not reach farmlands.The study also focuses on reducing pollution at the source by using cotton clothing and installing filters in washing machines [6,7]. These steps can greatly reduce microplastic release. Research findings support the success of this combined approach in lowering pollution and enabling safer water reuse. The proposed system offers a smart and green solution to support healthier cities and farming practices.
Keywords:*Microplastics, Graywater, Wastewater, Purification, AI-Supported Smart Irrigation Systems*

Introduction

Natural resources are limited and increasingly under pressure because of fast population growth and higher consumption. Plastic pollution is a serious global issue that affects almost every ecosystem. Microplastics tiny plastic pieces that come from broken-down larger plastics or are already included in everyday products can pollute water, harm animals, and create health risks for humans when they enter the food chain [1,3,7]. These particles do not break down easily and can stay in the environment for decades, making them a long-term threat.

A rising source of microplastic pollution is household wastewater, especially graywater. This includes all wastewater from daily household activities except toilet waste. It comes from showers, laundry, kitchen sinks, and washbasins. Graywater accounts for about 75% of total domestic wastewater [4]. While it is generally thought to be less dirty than toilet waste, it can still contain large amounts of microplastics, mainly from washing synthetic fabrics. Materials like polyester, nylon, and acrylic release thousands of microfibers in every wash [6].

In Turkey, over 80% of plastic-related water pollution comes from household sources [1]. As more cities turn to graywater reuse to cope with water shortages, concerns grow about the safety of this practice. Without treatment, microplastics in graywater can pollute soils, damage crops, and possibly reach people through food. Most existing treatment systems are not effective at removing microplastics, especially in small-scale or decentralized reuse setups.

Because of this, there is a need for smart, low cost, and scalable solutions to detect and control microplastics in reused water. This paper presents an AI-powered irrigation system with real-time fiber sensors. Along with efforts to reduce pollution at the source, this system provides a reliable way to safely reuse graywater especially in areas struggling with water scarcity.

Methodology

As a first step, we reviewed a range of sources to better understand how microplastics behave in graywater. This included academic studies, environmental reports, national guidelines, and previous research on laundry related fiber pollution. We were especially interested in how fabric type and washing habits affect microfiber release, and what kind of simple actions like using filters or choosing natural fabrics can prevent pollution before it reaches wastewater.To support this research, experimental data from previous studies were analyzed. For example, Napper and Thompson [6] found that a single 6 kg laundry load could release up to 700,000 synthetic fibers per wash. Further evidence indicated that using washing machine filters can reduce microfiber emissions by approximately 80%, while choosing cotton-based fabrics instead of synthetics can also significantly reduce microplastic release [6,7].

Building on these findings, the proposed solution is a smart irrigation system designed to operate with minimal human intervention. The system has three main parts.Microplastic sensors installed in irrigation pipes, capable of real time fiber detection based on light scattering or turbidity, an AI-based decision-making algorithm, which continuously interprets sensor data and determines whether the water quality is within acceptable thresholds and atwo path piping system, which automatically redirects contaminated water to a holding tank for non-agricultural use when microplastic levels exceed the safe limit.

The system can be integrated into both centralized irrigation networks and decentralized urban agriculture projects. Its modular design allows for scalability and adaptability, especially in areas with varying water reuse needs. A feedback loop within the AI algorithm enables learning from previous contamination events, improving decision accuracy over time.

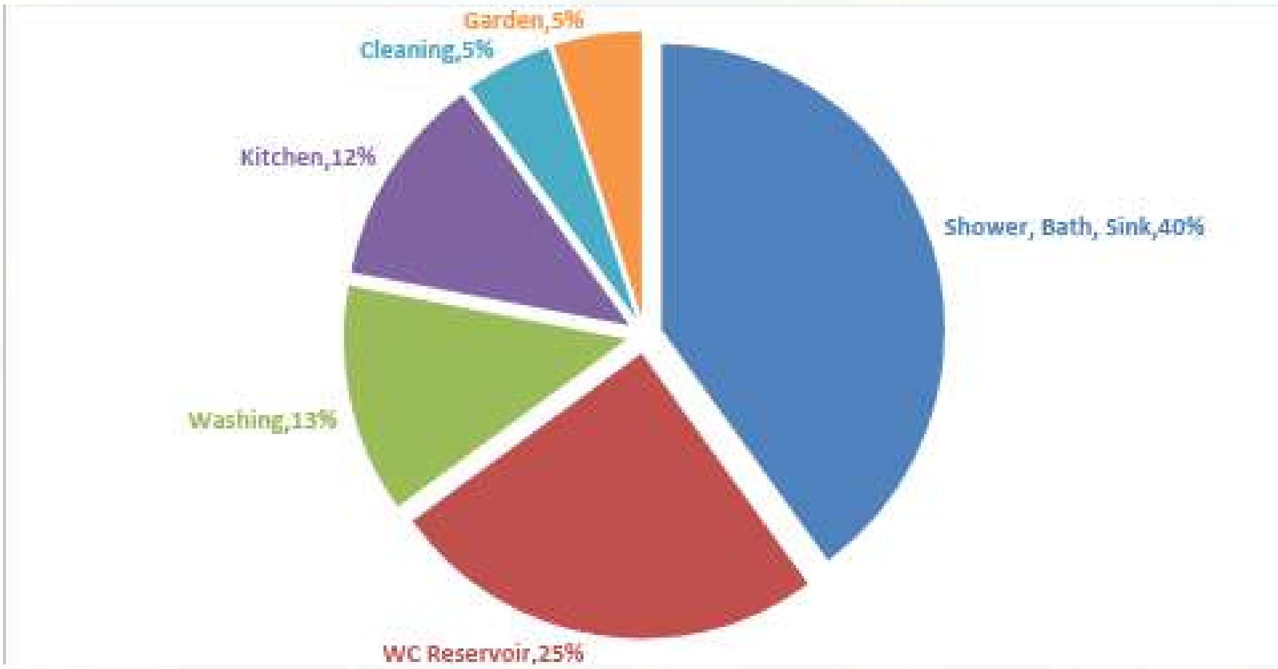
MainResults and Discussion

If graywater is used for irrigation without treatment, microplastics can build up in soil. These particles change the soil structure, reduce its ability to absorb water, and disturb beneficial microbes. In some cases, plants may absorb small microplastic particles through their roots, which can then enter the food chain [2, 3].

The AI-supported system helps prevent this by actively monitoring irrigation water. If fiber levels rise after a laundry cycle, for example, the system will stop irrigation and store the water for other uses like street cleaning, toilet flushing, or industry. Once sensors detect that fiber levels are safe again, the system automatically restarts irrigation.

This process reduces the need for constant manual checking and increases the system's ability to react quickly, which is especially important in areas with limited water treatment [4]. Also, promoting cotton clothing and washing machine filters at the household level lowers the amount of microplastics before they even enter graywater [6].

Altogether, the findings suggest that combining AI-based monitoring with pollution prevention at the source offers an effective, low cost, and scalable method for safe graywater reuse. This protects soil and crop health, and helps communities better manage water resources during times of scarcity.



Graphic 1. Daily Domestic Water Consumption Amounts [4].

Conclusion

Microplastic pollution in graywater is becoming a bigger issue as more cities turn to water reuse. This study shows that graywater (especially from laundry) can carry large amounts of microplastics, and if not properly treated, it can harm both the environment and human health.

The smart irrigation system introduced in this paper offers a practical solution. By detecting microplastic levels in real time and controlling the water flow, the system ensures that only clean water is used for farming. This helps protect soil, crops, and people.

Using natural fabrics and laundry filters further reduces the problem at its source, making the system even more effective. Together, these methods create a strong and future focused approach to sustainable water use. As cities grow and water becomes scarcer, systems like this will be vital for protecting health, food supply, and the environment.

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SOLID WASTE MANAGEMENT: A COMPARISON OF CONVENTIONAL AND TECHNOLOGICAL METHODS

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ABSTRACT

The rapid increase in global population, industrialization, and urbanization has significantly intensified the challenges associated with solid waste management (SWM). "Our country is notably rich in terms of organic waste."(1) Inadequate waste handling not only contributes to environmental degradation but also poses severe threats to human health and sustainable development. As cities expand, the need for efficient and environmentally conscious waste management systems becomes increasingly urgent. This paper aims to explore and compare conventional and smart waste management approaches by focusing on their operational structures, effectiveness, and sustainability outcomes. Traditional systems, primarily based on collection and landfilling, are linear and inefficient, often leading to resource loss and ecological damage. In contrast, smart systems integrate technologies such as the Internet of Things (IoT), Geographic Information Systems (GIS), artificial intelligence, and real-time data analytics to optimize waste handling, improve recycling rates, and reduce carbon emissions. Using Istanbul as a case study, this paper analyzes the transition from outdated practices to data-driven solutions, highlighting the economic, environmental, and social benefits of technological integration. A comparative analysis of past and present systems in Istanbul and other major Turkish cities is presented through visual data to demonstrate the growing adoption of smart systems. The study concludes that technological innovation in waste management plays a vital role in achieving urban sustainability and should be widely supported by policy, public awareness, and investment initiatives.

Key words: Waste Management, Smart Systems, Sustainability, Technological Integration

Introduction

With rapid urbanization and the growing global population, effective waste management has become one of the most pressing challenges facing cities today. Improper waste disposal leads to severe environmental pollution, resource depletion, and health risks. As traditional methods, primarily based on landfilling and manual collection, have proven inadequate in addressing the increasing waste generation, there is a pressing need for more sustainable solutions. In this context, the reuse and more rational utilization of resources have become increasingly important. "Solid waste generated as a result of rapid population growth and excessive consumption is now considered a significant resource that must be evaluated rather than discarded." (3)

This study focuses on comparing conventional waste management systems with smart technologies in managing solid waste. Conventional systems, often characterized by inefficient waste collection, lack of separation at source, and limited recycling, contribute to significant environmental degradation. In contrast, smart waste management integrates cutting-edge technologies such as the Internet of Things (IoT), data analytics, geographic information systems (GIS), and artificial intelligence (AI), which optimize waste collection, reduce environmental impact, and enhance resource recovery. “The main concept of smart waste management is to handle all the waste in the city and monitoring all the process.” (10)

This paper examines the transformation from traditional waste management systems to modern, tech-driven solutions. The primary aim of this research is to evaluate the effectiveness of smart waste management in comparison to conventional practices, emphasizing the environmental, economic, and social benefits of adopting smart technologies. This study will contribute to the growing body of knowledge on sustainable urban waste management solutions

Methodology

The research did not utilize fieldwork or surveys; instead, it examined only official documents and academic sources. Qualitative analysis was used instead of quantitative data. In this context, the study offers a comparison based on existing data, but it can be supplemented with future field research and expanded data analysis.
This project is being conducted using a comparative analysis method. Comparative analysis allows for the systematic examination of phenomena across different contexts within the framework of specific categories (Ragin, 2014). The study analyzed traditional and smart waste management methods to identify similarities and differences.

1. Study Universe

This research focuses on solid waste management practices in urban areas of Türkiye. Istanbul was selected as the primary case due to its significant transformation from conventional to smart waste management systems. Additionally, comparisons were made with medium-sized cities such as Eskişehir to investigate regional disparities and assess the scalability and applicability of smart waste management technologies in different urban contexts.

2. Data Sources

The study is based on secondary data obtained from a variety of reliable sources. These include peer-reviewed academic journals, conference proceedings related to waste management and smart city practices, and official reports and statistics from the Istanbul Metropolitan Municipality and the Ministry of Environment, Urbanization and Climate Change of Türkiye. International references, such as the United Nations Environment Programme (UNEP) and the World Bank’s “What a Waste 2.0” report, were also consulted. Furthermore, prior academic research providing case-specific analysis of Istanbul’s waste management processes contributed to the data set.

3. Data Analysis

A qualitative comparative analysis was conducted to evaluate the differences between traditional and smart waste management systems. The key dimensions of comparison included waste collection methods, storage and disposal techniques, recycling processes, data utilization, and citizen engagement. A temporal analysis was carried out by comparing Istanbul’s waste management practices from the 1950s with those implemented after 2020. The findings were illustrated through visual tools such as tables and charts. Technological tools, including Internet of Things (IoT) sensors, Geographic Information Systems (GIS), and mobile applications, were assessed in terms of their environmental, economic, and operational impacts.

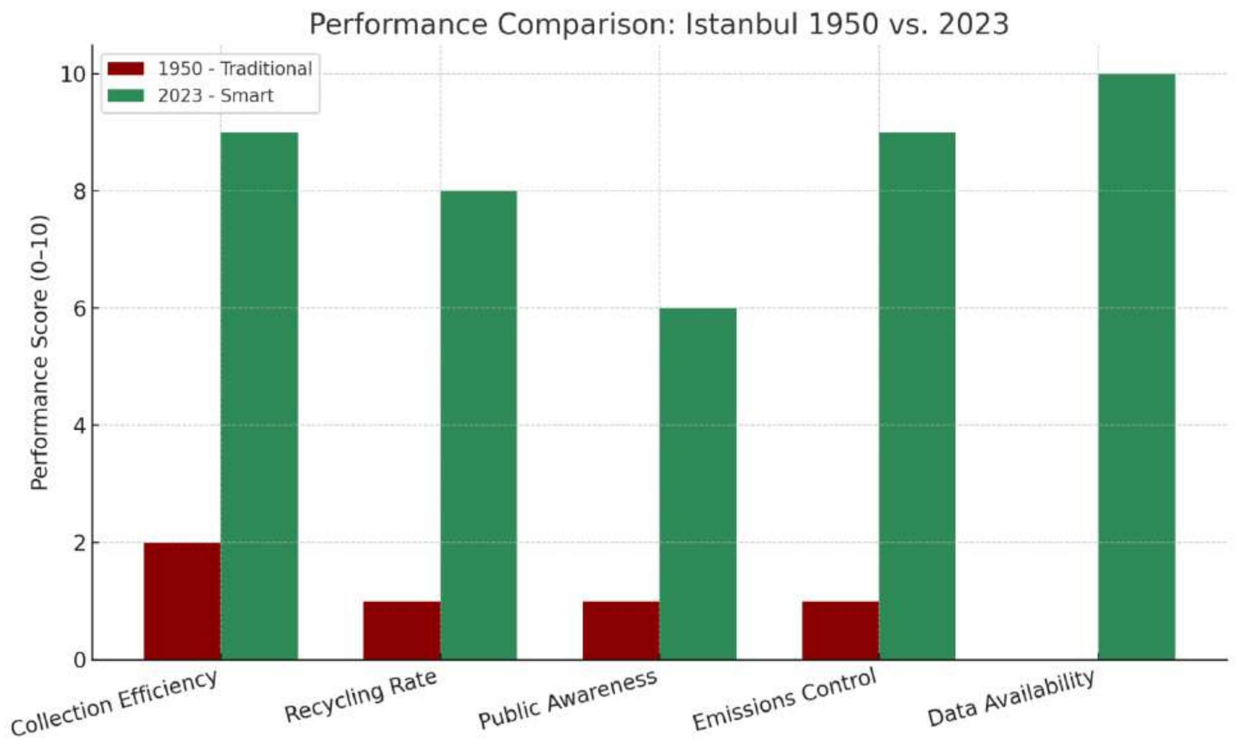
Main Results and Discussion

The comparative analysis of traditional and smart solid waste management systems reveals significant differences in their environmental, social, and economic impacts. These differences become increasingly relevant in the context of rapid urban expansion, growing population density, and the rising urgency of climate change mitigation. Traditional methods, characterized by non-separated waste collection and landfill disposal, have proven to be insufficient for modern urban demands. This inadequacy is particularly evident in densely populated metropolitan areas, where inefficient waste handling exacerbates pollution levels and strains municipal budgets. These practices not only lead to the loss of valuable resources but also cause environmental degradation through soil, air, and water pollution. The accumulation of untreated waste in landfills contributes to greenhouse gas emissions, leachate contamination, and habitat disruption, further highlighting the unsustainable nature of conventional approaches. Furthermore, traditional systems typically lack the infrastructure for recycling and reuse, and they fail to provide accurate data necessary for strategic planning. Without reliable data, municipalities are unable to forecast trends, allocate resources efficiently, or implement evidence-based policies, resulting in reactive rather than proactive waste management.

In contrast, smart waste management systems offer integrated, data-driven solutions by incorporating advanced technologies such as IoT sensors, real-time monitoring, Geographic Information Systems (GIS), artificial intelligence, and mobile applications. These innovative tools enable dynamic interaction between physical infrastructure and digital platforms, creating more adaptive and responsive service delivery models. These systems improve efficiency by optimizing collection routes, reducing fuel consumption, and minimizing operational costs. Through route optimization and predictive analytics, municipalities can significantly cut down on emissions and reduce wear on public service vehicles. The use of sensors to track bin fill levels ensures that collection is performed only when necessary, preventing overflow and reducing labor requirements. This not only conserves energy and labor but also enhances citizen satisfaction and public hygiene in urban spaces. Additionally, data analytics enable municipalities to forecast waste generation trends and develop proactive management strategies. Over time, such capabilities support long-term planning, facilitate circular economy practices, and contribute to sustainable urban development goals, making smart waste management a key pillar in future-ready city planning.

The case study of Istanbul illustrates this transformation clearly. In the 1950s, Istanbul followed a traditional approach: manual waste collection without separation, open dumping, and limited recycling awareness. This resulted in environmental hazards such as methane emissions, poor hygiene, and a lack of public engagement. By 2023, however, the city had adopted a smart system utilizing sensor-equipped bins, energy recovery facilities, and mobile platforms for public education and participation. These advancements have led to significant reductions in pollution and increased recycling rates, showcasing the tangible benefits of smart systems.

The comparison between traditional and smart waste management practices emphasizes that technological integration leads to better resource efficiency, improved public health, and enhanced sustainability. It also highlights the importance of citizen awareness and participation in ensuring the success of modern waste management initiatives. The shift from a linear to a circular model—where waste is treated as a resource rather than discarded—represents a pivotal step toward sustainable urban development.



The comparison of Istanbul's waste management practices between the 1950s and 2023 demonstrates a substantial transformation in operational efficiency, environmental protection, and public engagement. In terms of collection efficiency, the traditional system relied on manual collection at fixed intervals, resulting in waste accumulation on the streets, unpleasant odors, hygiene issues, and pest infestations. In contrast, the modern smart system employs sensor-equipped containers that provide real-time data on fill levels, enabling optimized collection routes and minimizing fuel consumption and emissions. Recycling efforts have similarly advanced; while the earlier system lacked infrastructure and awareness—leading to the loss of valuable materials—the current approach emphasizes source separation, allowing for the recovery of paper, plastic, glass, and organic waste through recycling and composting. Public awareness and participation, once minimal, have been significantly enhanced through the use of mobile applications, which inform citizens about collection schedules and recycling points, thereby promoting environmentally responsible behavior. Emission control has also improved markedly: where waste was once dumped in open areas leading to methane emissions and environmental contamination, today's waste is processed in energy recovery facilities such as incineration and biogas plants, reducing the need for landfilling and contributing to energy generation. Finally, the availability and use of data have seen a pivotal shift; previously absent, reliable data on waste types and quantities is now collected through IoT technologies and analyzed via big data tools, allowing municipalities to forecast trends and design evidence-based waste management strategies. This evolution reflects the broader shift from reactive, linear systems to proactive, circular models rooted in sustainability and technological innovation.

Conclusion

This study reveals that the integration of smart technologies into solid waste management systems plays a crucial role in addressing the growing environmental, social, and operational challenges faced by modern cities. Traditional waste management systems, which primarily rely on manual collection and landfill disposal, have been shown to be inefficient, environmentally harmful, and lacking in adaptability to increasing urban demands. The Istanbul case study illustrates how a transition to smart systems—incorporating technologies such as Internet of Things (IoT) sensors, Geographic Information Systems (GIS), and real-time data analytics—can significantly enhance waste collection processes, reduce emissions, and improve overall efficiency.

Smart waste management systems not only enable better monitoring and optimization of waste-related operations but also foster citizen engagement and data-driven decision-making. These systems support a shift from reactive and linear models of waste handling toward proactive and circular approaches, where waste is viewed as a valuable resource rather than as a disposable burden. The implementation of such systems has been shown to improve public hygiene, reduce greenhouse gas emissions, and increase recycling and energy recovery rates.

The findings of this study emphasize the importance of adopting smart waste management technologies as a fundamental component of sustainable urban development. For cities aiming to meet environmental targets and manage resources effectively, investment in technology, policy support, and increased public awareness are essential. The Istanbul experience underlines how strategic use of technology can lead to measurable improvements in both environmental outcomes and urban quality of life.

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Deep Learning Based Route Optimization in Urban Waste Collection

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ABSTRACT

With increasing urbanization, waste management has become a critical element in the resource planning of municipalities. In particular, the planning of waste collection routes both increases operational efficiency and provides significant savings in resource utilization. Today, these processes are mostly carried out by manual methods and are insufficient in terms of adaptation to real-time conditions. In this study, it is aimed to optimize waste collection routes using location data of garbage containers in Karatay district of Konya province. In addition to the classical Travelling Salesman Problem (TSP) algorithm, two different deep learning models based on Deep Q-Network (DQN) and Graph Convolutional Network (GCN) were developed. Each of the models was trained to generate routes for containers belonging to a specific sector and the generated routes were compared in terms of total distance and computation time. According to the results obtained, in some sectors, the GCN model was able to produce shorter routes than the classical TSP algorithm, while the DQN model produced routes in a longer time and showed high deviations in some cases. In addition, through the mobile application developed, all model outputs were visualized comparatively, and operational management of field teams was supported.

Keywords: Route optimization, deep learning, waste collection, smart city

Introduction

Waste collection operations are among the essential services under the responsibility of municipalities and play a crucial role in ensuring the sustainability of urban life. With the rapid growth of urban populations, these services have become a critical operational challenge for local governments. Managing such processes entails the effective coordination of numerous parameters—including vehicles, containers, personnel, and fuel—leading to significant operational costs. Currently, many municipalities plan waste collection routes based on past experience and the personal judgment of field personnel. Although such an approach allows the system to operate to a certain degree, it also leads to issues such as planning inefficiencies, fuel waste, and labor productivity loss. In order to overcome these problems, various meta-heuristic algorithms, especially Genetic Algorithm and Ant Colony Optimization, have been proposed in recent years to optimize waste collection routes more efficiently [1]. However, although these methods can produce acceptable solutions when the number of nodes is large, their rigid structures often fall short of adapting to real-time and dynamic conditions. TSP, widely used in the literature, is an effective optimization method for identifying the shortest route [2]. Yet, as the number of nodes increases, the solution space grows exponentially, substantially increasing computation time [3]. With the advancement of artificial intelligence, AI-based methods capable of responding to real-time and dynamic system requirements have gained prominence. Reinforcement Learning (RL) approaches, which allow the system to learn decision-making strategies through continuous interaction with the environment, offer a significant alternative. However, traditional RL methods often struggle in high-dimensional problem spaces. To address this, Deep Reinforcement Learning (DRL) architectures have been developed, incorporating deep neural networks into decision-making processes to offer a more flexible and generalizable framework. DQN architecture, in particular, has been employed in route planning applications that require sensitivity to environmental changes [4].

Yue et al. achieved successful results in time-constrained vehicle routing problems using Q-learning-based ant colony optimization [5]. Shoab and Alotaibi, on the other hand, achieved low latency and high efficiency in heterogeneous networks by using DQN-based routing systems [6]. Moreover, since road networks inherently possess a graph-based structure, architectures such as GCN can be meaningfully and effectively applied in this domain. GCN-based models, which take topological relationships between locations into account, offer distinct advantages in decision-making processes. Almasan et al. combined GCN and DRL techniques to build effective routing systems in dynamic networks [7]. Similarly, Monemi et al. successfully adapted GCN-based architectures to logistics optimization problems [8].

In this study, an artificial intelligence supported approach is proposed to make waste collection processes more efficient, flexible and suitable for digital transformation. In the system developed by considering the container locations in Karatay district of Konya province, containers are divided into manageable subgroups by considering operational constraints (waste collection capacity of vehicles, etc.) and route optimization for these subgroups is performed by deep learning methods. In this context, two different artificial intelligence models based on DQN and GCN, as well as the TSP algorithm, which is the frequently preferred classical optimization method to find the route that provides the shortest total distance, were evaluated comparatively. In addition, a Flutter-based mobile application has been developed to increase the usability of these models by field teams. Through the application, the routes generated by different models were visualized and made directly integrable into field operations. Thus, this study provides an artificial intelligence-based flexible and learnable route planning infrastructure that contributes to the digitalization process of municipalities and enables the structuring of waste collection processes to the vision of smart urbanism.

Methods

1. Data Collection and Preprocessing

In this study, real-world field data from the Karatay district of Konya, Türkiye, were used to optimize the collection routes for municipal waste containers. For the analysis and modeling processes, a snapshot of the dataset taken at the time of download was used as the reference. The dataset contains parameters such as the geographical location of each container (latitude, longitude), container type (IsUnderground), planned emptying cycle (Cycle), assigned zone (AssignedAreaId), and zone boundaries (Border). In total, data for 2,031 containers and nine collection sectors were available. The locations of the containers were specified by GPS coordinates, and both above-ground and underground containers were represented in the dataset. The collection cycle parameter refers to the emptying frequency of containers (e.g., daily or weekly). During preprocessing, missing or incorrect coordinate data were removed, and duplicate records were cleaned. Containers were then grouped based on their geographical coordinates and collection frequencies. For this purpose, K-Means and Agglomerative Clustering algorithms were applied, producing homogeneous regions according to geographical proximity and collection requirements. This step shortened the runtime of the route optimization algorithms and contributed to achieving balanced routes.

2. Sectorization

To improve model scalability and reduce computational load, containers were divided into manageable sectors. These sectors were defined based on geographical proximity and the operational capacity of the municipality. Each sector was treated as an independent route optimization problem, with model training and evaluation performed separately for each sector. This approach enhanced both model performance and operational feasibility.

3. Container Types

Waste containers used in the Karatay district vary in terms of volume, material, and usage type. They are manufactured from different materials such as galvanized metal or plastic and are designed for either above-ground or underground use. Depending on their intended purpose, some containers are large-capacity units that can be emptied using cranes, while others are standard-sized containers suitable for manual handling. Capacities are measured in cubic meters and classified according to waste type, regional needs, and usage frequency. This diversity allows for the design of efficient waste collection processes tailored to different areas. Within the scope of this study, information on all container types in the district was recorded in the relevant database.

4. Travelling Salesman Problem

The Travelling Salesman Problem (TSP) is a classical combinatorial optimization problem that aims to visit a given set of locations exactly once and return to the starting point with the shortest total distance [9]. In this study, the TSP was modeled in the context of visiting waste containers using the most efficient route. As a baseline approach, a greedy algorithm was applied: starting from the waste collection facility, at each step, the nearest unvisited container to the current position was selected. Once all containers were visited, the route returned to the starting point. This method served as a benchmark for comparing the performance of more complex models.

5. Deep Q-Network

The Deep Q-Network (DQN) is a reinforcement learning method that combines the classical Q-learning algorithm with deep neural networks to approximate the state–action value function [4]. In this study, each state represented the currently visited container and the visitation status of all other containers. Actions corresponded to selecting the next container to visit. A fully connected neural network with two hidden layers, each containing 256 neurons and using the ReLU activation function, was designed to approximate Q-values. During training, the agent operated in a custom-built OpenAI Gym environment, using an epsilon-greedy strategy to balance exploration and exploitation. A replay buffer was employed to store past transitions, improving training stability. The loss function was defined as the Mean Squared Error (MSE) between the predicted and target Q-values.

6. Graph Convolutional Network

A Graph Convolutional Network (GCN) is a deep learning architecture used to model relationships between nodes in graph-structured data [10]. In this study, each sector was represented as a graph, with nodes corresponding to containers and edges representing the distances between them. Edge weights were based on road distances obtained via the OpenRouteService API. Node features included container coordinates and visitation status. A two-layer GCN architecture was implemented: the first layer transformed input features into 64-dimensional hidden embeddings, while the second layer produced scalar values representing the likelihood of each node being the next destination. Among unvisited nodes, the one with the highest score was selected as the next target. The model was trained within a reinforcement learning framework using a reward function based on route efficiency, and the loss function was defined as the MSE between predicted and optimal steps.

Results and Discussion

To evaluate the performance of the three route optimization methods (TSP, DQN, and GCN), 15 randomly selected waste collection sectors within the Karatay district were used as test scenarios. Each model was tasked with generating the most efficient route to collect waste from containers within its assigned sector. The evaluation was based on two main criteria: total route distance (in kilometers) and computation time (in seconds).

Figure 1 presents a comparison of route computation times (in seconds) for the DQN, GCN, and TSP algorithms across different sectors. As shown in the figure, the DQN model exhibited significantly longer computation times compared to the other methods. This can be attributed to the DQN model's reinforcement learning and decision-making mechanisms, which inherently involve higher temporal complexity. Notably, in sectors 1075-0 and 1081-2, computation times exceeded 150 seconds. In contrast, the GCN model achieved much shorter computation times than DQN, completing its tasks in durations close to those of the TSP algorithm across many sectors. The shortest computation time was recorded in sector 1077-8. These results indicate that GCN, by leveraging its graph-based structure, can make faster routing decisions than DQN. On the other hand, the TSP algorithm consistently demonstrated the shortest computation times across nearly all sectors. This is primarily due to the deterministic and often greedy nature of TSP solutions, which are optimized for efficiency. Overall, this comparison highlights that in terms of computation time, TSP is the most time-efficient method, while GCN and DQN may be inadequate for certain sectors.

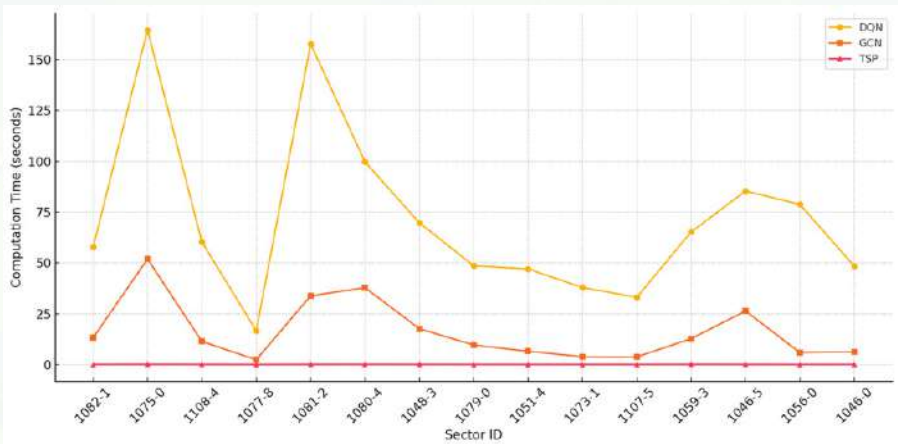


Figure 1. Model-based route computation time comparison for waste collection sectors

Figure 2 shows the comparison of route distances (in kilometers) generated by DQN, GCN, and TSP algorithms for each sector. As illustrated, the routes produced by DQN were significantly longer than those of GCN and TSP in sectors 1108-4 and 1107-5. This suggests that in certain sectors, DQN may follow longer paths due to excessive exploration behavior. However, in sectors 1075-0, 1073-1, and 1056-0, DQN generated shorter routes than GCN. Still, it failed to outperform TSP in any of the tested cases. GCN, on the other hand, produced route lengths that were generally close to those of TSP, except in sector 1075-0. In fact, in sectors 1059-3 and 1046-0, GCN managed to generate shorter routes than TSP. As expected, TSP frequently achieved the shortest route distances across the board.

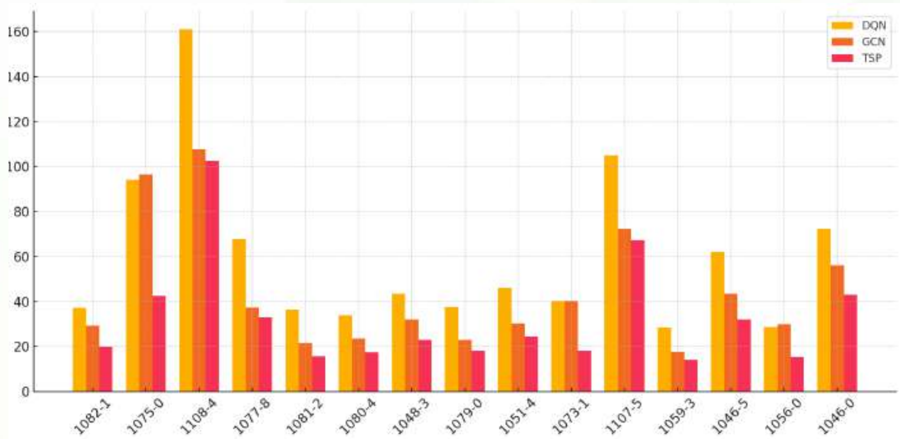


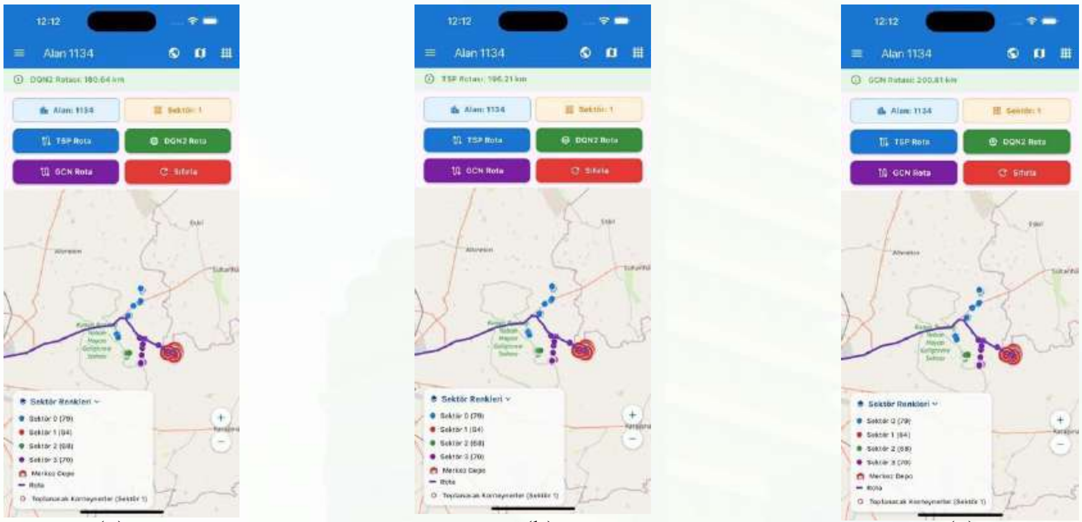
Figure 2. Comparative analysis of route distances generated by models

Table 1 summarizes the overall performance of the models. Here, the Optimal Ratio is used to compare each model's performance against the reference model, TSP.

Table 1. Performance metrics and optimality ratios of models for route planning

Model	Avg. Distance (km)	Std Distance (km)	Avg Runtime (sn)	Std Runtime (sn)	Optimal Ratio Distance	Optimal Ratio Time
DQN	60	37	71	42	1.8	991
GCN	44	28	16	15	1.4	225
TSP	33	24	0.07	0.02	1	1

The classical TSP algorithm was designated as the optimal baseline with an average route distance of 33 km and an average computation time of 0.07 seconds. While the DQN model offered high flexibility, it produced the longest average routes (60 km) and required the most time (71 seconds). This corresponds to an optimality ratio of 1.8 in terms of distance and 991 in terms of computation time. The GCN model provided a more balanced performance, with an average route distance of 44 km and an average computation time of 16 seconds (distance ratio: 1.4; time ratio: 225).



(a) (b) (c)

Figure 3. Route visualizations on the developed mobile application: a)DQN b)TSP c)GCN

As shown in Figure 3, the developed mobile application provides a visual comparison of waste collection routes in the Karatay district, generated by the DQN, TSP, and GCN algorithms through the developed mobile application. The DQN algorithm (a), as previously shown in Figures 1 and 2 and Table 1, produced the longest average route distances at approximately 60 km and the highest computation times of 71 seconds. This resulted in more winding routes that pass through additional nodes, as seen in the visualization. The TSP algorithm (b) achieved the shortest average distances of around 33 km and the fastest computation times at 0.07 seconds, resulting in more compact route lines that directly connect the target points. The GCN algorithm (c) generated routes with an average distance of approximately 44 km and a computation time of 16 seconds, producing paths close to those of the TSP but with greater flexibility. While the route structures in this algorithm generally resemble those of the TSP, different node sequences were preferred in certain sectors.

Conclusion

This study presents a comparative analysis of artificial intelligence-supported route optimization methods for urban waste collection. Utilizing real-world geographic location data obtained from Karatay Municipality, three models—TSP, DQN, and GCN—were implemented and evaluated in terms of route efficiency and computational performance. The classical TSP algorithm served as a strong baseline, delivering rapid and generally optimal solutions. The GCN-based approach, which leverages the spatial structure of the container network, outperformed TSP in certain scenarios. While the DQN model exhibited inconsistent performance and longer computation times, it demonstrated potential for reinforcement learning-based decision-making, particularly in dynamic environments. Furthermore, integrating all three models into a mobile application significantly enhanced their operational usability by providing comparative route visualizations for field teams. In conclusion, the GCN model offers a more practical alternative for real-time waste collection applications by striking a reasonable balance between solution quality and computational cost. Future research may explore the development of adaptive hybrid models, the integration of real-time GPS, traffic, and environmental data to dynamically adjust routes during operations, and the use of cloud-based inference systems to improve scalability and response time. Additionally, expanding the model to handle multi-depot waste collection scenarios and incorporating vehicle capacity constraints could further enhance its applicability in large-scale urban waste management systems.

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Sustainable Smart-Green Campuses in the Context of Resilience: The Cases of ITU Ayazağa and Manisa Celal Bayar Central Campuses

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ABSTRACT

University campuses play a significant role in the holistic integration of sustainability, resilience, and smart city concepts. Universities must prioritize not only achieving sustainability goals but also preparing for the future with resilient structures, robust technological infrastructures, and flexible governance models. Establishing smart, green, and resilient campuses is of vital importance, particularly for countries located in regions with high disaster risk. This study questions to what extent the widely used UI Green Metric system for evaluating sustainable campuses reflects the concept of "resilience" in campuses located in earthquake-prone areas. Taking Istanbul Technical University's Ayazağa Campus—one of Türkiye's leading technical universities—and the developing Central Campus of Manisa Celal Bayar University as case studies, the performance of these campuses is comparatively analysed within the context of resilience. Furthermore, the importance of integrating smart systems into campus infrastructures is emphasized. As a result, increasing interest in green campus practices holds strategic importance not only for environmental and economic benefits but also for enhancing social resilience. The proliferation of such campuses constitutes an effective tool in both combating climate change and building resilient cities and communities against disaster risks.

Key words: sustainable smart-green campus, resilience, UI GreenMetric

Introduction

Today, university campuses are not only centres for knowledge production and dissemination but also serve as spaces where globally critical concepts such as sustainability, technological innovation, and disaster resilience are tested and embodied. The global climate crisis, the increasing risk of natural disasters, and the environmental pressures generated by urbanization necessitate a rethinking of traditional campus planning approaches, urging a restructuring of campuses through green, smart, and resilient systems [1]. While campuses are planned with the goal of ensuring environmental sustainability through energy efficiency, water management, and waste reduction, various disasters experienced in recent years in Türkiye have brought the concept of "resilience" to the forefront [2]. Resilience refers to the capacity to withstand natural disasters, climate change, and other potential crises.

Strengthening infrastructure, establishing emergency plans, and preparing communities for such situations are all addressed within the scope of resilience [3]. Moreover, in countries exposed to disasters such as earthquakes, floods, and fires, not only sustainability but also rapid recovery and infrastructural robustness during crises are of critical importance. The relationship between sustainability and resilience is complex and multifaceted. While sustainability focuses on future-oriented goals through the efficient use of resources, resilience centres on maintaining existing assets and functionality in the face of sudden and disruptive events. For a country like Türkiye, located on active fault lines, this distinction represents a vital necessity that current evaluation systems fail to address adequately. Although resilience is performance included among the ranking criteria of systems that evaluate campus sustainability performance, it can be indirectly assessed through sustainability themes such as energy and climate change, waste management, water management, and transportation.

In the 21st century, with the advancement of the internet and technology, smart applications have come to the forefront to address current problems and make settlements more liveable. Regardless of scale, the concept of smart buildings or campuses is defined as self-sufficient entities that use energy efficiently, are sensitive to disasters and the environment, ensure security, prioritize comfort, and adapt to user needs. Smart, green, and resilient campuses can be described as innovative settlements that integrate technology with environmental, economic, and social sustainability, as well as disaster resilience. These campuses should ensure sustainability through renewable energy resources, smart buildings, and automation systems, while also possessing the capacity to recover rapidly in times of crisis.

In this context, the aim of the study is to reassess the concept of sustainable campuses through the lens of resilience; to question the adequacy of current systems in this regard; and to reveal the contribution of smart-green campus practices to the overall resilience level of society. The significance of the study stems not only from offering an academic analysis, but also from providing concrete findings that can guide policymakers, local administrators, and campus planners—particularly in a country like Türkiye that is situated in a high-risk disaster zone. Accordingly, the study aims to present a comprehensive perspective on how environmental sustainability and social resilience can be integrated on the campus scale. Sustainable settlements or green campuses stand out as university campuses designed to promote environmentally friendly infrastructure and sustainable lifestyles.

In disaster-prone countries such as Türkiye, the concepts of sustainability and resilience must be considered together. The relationship between resilience and sustainability should also be emphasized in systems that assess the sustainability performance of universities, such as the UI GreenMetric, and in the future, resilience indicators should be incorporated into the ranking criteria. An examination of campuses in Türkiye reveals an increasing number of green campus projects, while the aspect of resilience is often overlooked. However, in the face of disaster risks, it is not sufficient for green campuses to be sustainable alone; resilient infrastructures and effective disaster management systems must also be integrated. In this regard, collaboration among universities, ministries, public institutions, and local governments is essential to ensure that campuses are both environmentally sensitive and disaster resilient.

Methodology

The concept of sustainable campuses has evolved significantly over the past two decades, driven by growing environmental awareness and institutional commitments to carbon neutrality. Universities worldwide have adopted various sustainability frameworks, with the UI GreenMetric World University Rankings emerging as the most widely recognized evaluation system. Established in 2010 by the University of Indonesia, this ranking system evaluates universities based on six main categories: Setting and Infrastructure (15%), Energy and Climate Change (21%), Waste (18%), Water (10%), Transportation (18%), and Education and Research (18%) [4]. The UI GreenMetric system has successfully motivated universities to implement comprehensive sustainability programs, leading to significant improvements in energy efficiency, waste reduction, and environmental education. However, the system's focus on operational sustainability metrics, while valuable, creates a potential blind spot regarding institutional resilience and disaster preparedness.

This study re-centres the often-overlooked concept of “resilience” in sustainable campus evaluation approaches, taking as examples two campuses in Türkiye that differ in scale and context: Istanbul Technical University’s Ayazağa Campus and Manisa Celal Bayar University’s Central Campus. In the study, the UI Green Metric performances of these two campuses [4], as well as their physical infrastructures, governance models, and technological capacities, are evaluated from the perspective of resilience. Furthermore, the integration level of smart systems into these structures is examined, and suggestions are developed for a campus model that is prepared for disasters, sustainable, and technologically equipped. This study employs a comparative case study approach to analyse the relationship between sustainability performance and resilience capacity in Turkish university campuses. The research methodology combines quantitative analysis of UI GreenMetric data with qualitative assessment of resilience indicators across multiple campus systems. Workflow chart is given in Figure 1.

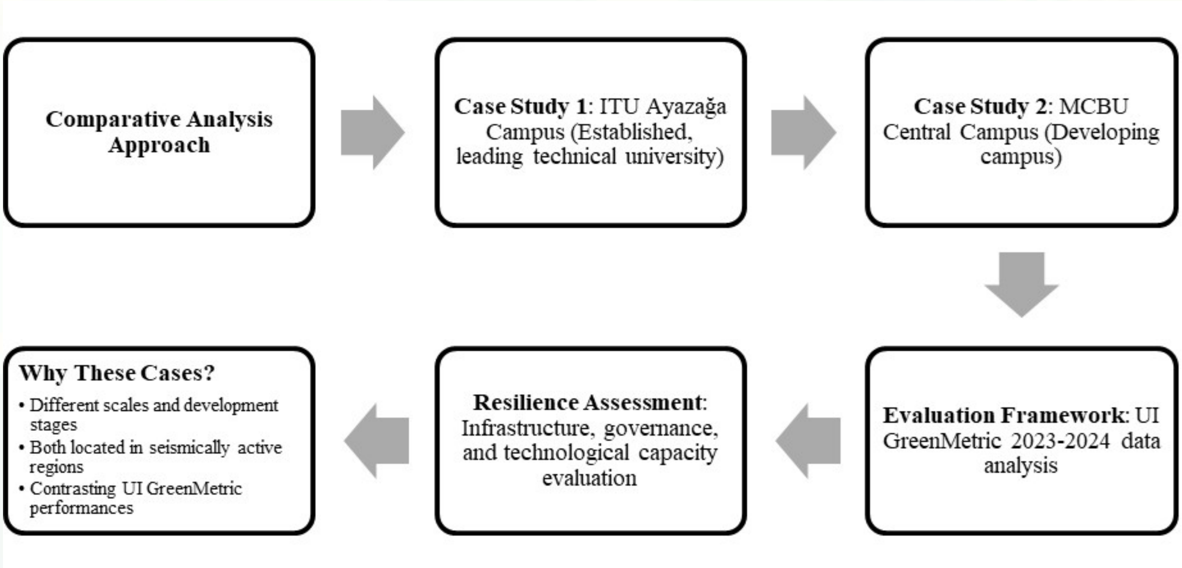

Figure 1. Workflow chart.

Main Results and Discussion

1. Case Studies: ITU Ayazağa Campus and MCBU Central Campus

ITU’s exceptional UI GreenMetric performance establishes it as a leading sustainable campus in Türkiye and globally. The university’s strong engineering background, advanced technological infrastructure, and comprehensive sustainability programs create substantial advantages for resilience development.

Resilience Strengths:

- Strong engineering expertise applicable to seismic risk assessment and mitigation
- Advanced technological infrastructure providing foundation for smart emergency systems.
- Comprehensive sustainability programs demonstrating institutional capacity for complex system management.
- Research capabilities in earthquake engineering, disaster management, and emergency planning.

Resilience Concerns:

- High seismic risk location in Istanbul, with major earthquake expected in coming decades.
- No systematic resilience assessment despite high sustainability scores
- Potential structural vulnerabilities unknown due to absence of resilience metrics
- Large campus population (over 30,000 students and staff) creating complex evacuation and shelter challenges.

MCBU represents a developing campus with growing sustainability commitment and significant opportunities for resilience integration from early development stages.
Resilience Opportunities:

- Developing infrastructure allows initiative-taking resilience planning and integration
- Smaller scale facilitates comprehensive resilience system implementation.
- Growing sustainability commitment indicates institutional capacity for resilience programming.
- Regional location provides opportunities for community resilience collaboration.

Resilience Challenges:

- Lower current sustainability performance indicates resource and capacity constraints.
- Need for accelerated resilience planning to match sustainability development.
- Limited technological infrastructure requiring coordinated development.
- Moderate seismic risk still requiring comprehensive preparedness planning.

2. UI GreenMetric Performance Analysis

When the data from the 2023–2024 period of the UI GreenMetric are analysed, a notable difference is observed between the two universities in terms of ranking and scores. ITU ranks first in Türkiye and is among the top 40 universities globally (Total Score: 8800), demonstrating international success in the field of sustainability. When examined categorically, ITU received near-maximum scores in the high-weighted categories (Table 1). These scores validate the university's well-established and successful practices in areas such as energy efficiency, the use of renewable energy, waste recycling programs, sustainable transportation policies, and academic activities focused on sustainability. On the other hand, Manisa Celal Bayar University has made considerable progress in recent years, reaching 49th place in Türkiye and 509th place globally (Total Score: 6675). MCBU's scores indicate a strong potential for further development.

Table 1. Comparison of UI GreenMetric Scores: ITU vs. MCBU [5]

2024 Ranking	Istanbul Technical University #38	Celal Bayar University #509
Setting & Infrastructure	1175	1075
Energy & Climate Change	1700	1500
Waste	1650	1050
Water	900	500
Transportation	1650	1275
Education & Research	1725	1275
Total Score	8800	6675

2. Sustainability and Resilience

While sustainability focuses on future-oriented goals through the efficient use of resources, resilience centres on maintaining existing assets and functionality in the face of sudden and disruptive events. For a country like Türkiye, located on active fault lines, this distinction is a vital necessity. A review of the six main categories of the UI GreenMetric system clearly reveals the absence of resilience-related metrics.

- ***Setting & Infrastructure:***

This category evaluates elements such as the proportion of green space, the campus budget allocated to sustainability investments, and accessibility for disabled individuals. However, it lacks indicators that directly assess resilience, such as the seismic performance of buildings, compliance of the existing building stock with earthquake regulations, structural safety of critical infrastructure (e.g., data centres, laboratories, power plants), or the adequacy of designated emergency assembly areas. Although ITU Ayazağa Campus, with its strong engineering background, possesses structurally sound buildings, its score does not provide data to support this assumption.

- ***Energy & Climate Change:***

This category measures energy efficiency and the use of renewable energy sources. However, it omits resilience-focused metrics such as redundant energy systems capable of off-grid operation after a potential earthquake, microgrids, or the capacity of uninterruptible power supplies to sustain vital units during emergencies. A high UI GreenMetric score in Energy & Climate Change does not guarantee that a campus could maintain essential functions (shelter, communication, first aid) for hours or days following a major power outage.

- ***Waste:***

This category assesses environmental performance in daily operations through recycling rates, organic waste processing, and hazardous waste disposal. ITU's high score in this area indicates the presence of a well-established system. However, it completely overlooks disaster scenarios. Questions remain unanswered, such as how tons of debris generated by a potential earthquake would be managed, whether there is temporary on-campus waste storage capacity if regular collection services are disrupted, or whether an emergency protocol exists for an anticipated increase in medical waste. A resilient campus should have a resolute "Disaster Waste Management Plan."

- ***Water:***

While this category focuses on water conservation and reuse, it does not assess critical resilience components such as access to clean water after a disaster, emergency water storage capacity, or the availability of alternative water sources.

- ***Transportation:***

This category evaluates efforts to reduce motorized vehicle use on campus, promote cycling and pedestrian pathways, and support zero-emission vehicles. ITU's high Transportation score reflects its success in reducing its carbon footprint. However, these metrics do not measure emergency organization or evacuation capacity. Can pedestrian walkways and narrowed vehicle roads allow tens of thousands of people to evacuate the campus quickly and safely during a panic situation? Are there designated corridors that remain unobstructed under all conditions to ensure unrestricted access of emergency vehicles (e.g., fire trucks, ambulances) to every point on campus? The UI GreenMetric score overlooks the potential contradiction between transportation efficiency during normal times and evacuation effectiveness during crises.

- ***Education and Research:***

This category measures the number of courses and publications related to sustainability. However, it fails to adequately emphasize practical metrics such as disaster awareness training, regular earthquake drills, the existence and effectiveness of campus emergency response plans, or resilience-focused R&D projects.

Conclusion

In the process of integrating the concepts of sustainable, resilient, and smart cities through a comprehensive approach, university campuses play a crucial role. The goal is not to choose between sustainability and

resilience, but to recognize their fundamental interconnection in creating truly sustainable campus communities. In an era of increasing environmental and disaster risks, this integration represents both an urgent necessity and a transformative opportunity for higher education's contribution to societal wellbeing.
In this context, university campuses should not only aim to achieve sustainability goals but also prioritize preparedness for the future through resilient structures, robust technological infrastructures, and flexible governance models. The omission of smart and resilient campus criteria from widely adopted international evaluation systems poses a significant risk. Universities with high UI GreenMetric scores are often labelled as "fully sustainable," yet they may, in fact, be structurally and functionally "fragile." Given the high seismic risk of Istanbul, where ITU is located, the university's operational success in sustainability does not guarantee its physical or functional resilience during a disaster. Similarly, considering the earthquake risk in Manisa and its surroundings, integrating a resilience perspective into MCBU's sustainability efforts is not merely a choice but a strategic necessity. This study reveals a critical gap between sustainability performance and disaster resilience in university campus evaluation and planning. The analysis of ITU Ayazağa and MCBU Central campuses demonstrates that high UI GreenMetric scores, while indicating strong environmental performance, provide no assurance of disaster preparedness capacity.

The systematic absence of resilience indicators across all UI GreenMetric categories creates a dangerous illusion of comprehensive campus preparedness. Universities achieving high sustainability scores may actually possess significant vulnerabilities to seismic events, power outages, water system failures, and other disaster scenarios. For Türkiye, with its high seismic risk and recent earthquake experiences, this gap represents an urgent policy and planning challenge. The integration of resilience criteria into campus evaluation systems is not merely an academic exercise but a strategic necessity for protecting university communities and supporting broader societal resilience. Universities have the opportunity to lead this integration, serving as living laboratories for sustainable-resilient community development. However, realizing this potential requires acknowledgment of current gaps, commitment to comprehensive planning approaches, and investment in systems that serve both environmental and safety objectives.

True and holistic sustainability must encompass not only environmental performance under normal conditions but also the capacity to withstand shocks, adapt to disruptions, and maintain core functions in times of crisis. The research findings point toward the need for a new paradigm of "smart-green-resilient" campus development that integrates environmental sustainability, technological innovation, and disaster preparedness into a coherent framework. This integration requires coordinated action across multiple levels: international evaluation systems, national policy frameworks, institutional planning processes, and academic research programs. Therefore, evaluation systems such as UI GreenMetric should retain their current metrics while also developing new indicators that focus on resilience and smart systems, especially for institutions located in risk-prone geographies. These indicators should address areas such as structural reinforcement, emergency management, community preparedness, and the development of technological infrastructure. Otherwise, the prestigious "green campus" titles awarded may risk losing their significance in the face of inevitable natural disasters. True sustainability must encompass not only environmental performance under normal conditions but also the capacity to withstand shocks, adapt to disruptions, and maintain core functions in times of crisis. Only through this comprehensive approach can university campuses fulfil their potential as models for resilient, sustainable communities prepared for an uncertain future.

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Progressive Collapse Response of Turkish Earthquake Code-Designed Low-Rise RC Buildings Following Dual Column Loss

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ABSTRACT

This study numerically evaluates the structural resistance of critical reinforced concrete buildings, designed according to the Turkish Building Earthquake Code (TEC-2018), against the progressive collapse mechanism. For the analysis, a 7-story RC frame building was modeled in accordance with the GSA-2016 and UFC 4-023-03 guidelines. Using the nonlinear dynamic analysis method, a sudden loss of column pairs at different locations (corner, edge, and interior) on the 1st and 4th stories were simulated. The nonlinear behavior of the structural members was defined using the automatic plastic hinge assignment method based on the lumped plasticity theory. The results revealed that the seismically designed structure resisted total collapse, while the damage remained localized around the removed columns. The most critical scenario was identified as the loss of the interior column pair, which led to the highest permanent displacements. Furthermore, it was determined that column removal on upper stories caused larger deflections compared to the ground story. These findings indicate that the indirect robustness provided by TEC-2018 is not sufficient on its own, demonstrating that the integration of direct design approaches is essential to mitigate the risk of progressive collapse.

Key words: Progressive collapse, Nonlinear dynamic analysis, Reinforced concrete, Government buildings occupancy class, Turkish building earthquake code.

Introduction

During their service life, structures may encounter unexpected incidents such as accidents, intentional attacks, improper usage, etc. Since such events are typically not accounted for in standard design procedures, they can result in significant human and economic losses [1]. One of the most significant global examples of progressive collapse is the 1995 bombing of the Alfred P. Murrah Federal Building in Oklahoma City, which resulted in the loss of 168 lives and hundreds of injuries [2]. A notable example from Turkey is the 2016 terrorist attack on the Elazığ Police Headquarters, which led to the death of three police officers and injuries to 217 individuals [3]. These targeted buildings sustained extensive structural damage.

An initial localized failure triggered by an extreme event can propagate through adjacent structural components, ultimately leading to the collapse of a disproportionately large portion of the structure or even its entirety. This cascading failure mechanism is referred to *as* progressive collapse (PC) [4]. The U.S. General Services Administration (GSA-2016) [5] and the U.S. Department of Defense (UFC 4-023-03) [6] incorporate direct design methods that involve simulating the sudden removal of columns at specific locations to analyze progressive collapse in existing and new military and government buildings. These guidelines aim to evaluate the progressive collapse response of such structures.

Conversely, conventional structural design standards—such as Eurocode 2 [7], ASCE 7-16 [4], and the International Building Code (IBC) [8]—do not offer explicit provisions for mitigating the risk of progressive collapse. Instead, these codes adopt indirect design approaches, which seek to enhance structural robustness by ensuring adequate strength, ductility, and redundancy. Additionally, it is well recognized that proper seismic detailing, as outlined in modern seismic design codes, contributes to improving a structure's resistance to progressive collapse [1]. Nevertheless, since progressive collapse is not explicitly addressed or assessed in these standards, the risk associated with such failures cannot be entirely eliminated.

Given Turkey's location in a highly seismic region, the Turkish Building Earthquake Code (TEC-2018) [9] was published in alignment with recent scientific advancements. While TEC-2018 aims to enhance structural integrity during extreme events by promoting overall robustness, it does not incorporate explicit direct design approaches for preventing progressive collapse.

In this study, the progressive collapse behavior of RC buildings classified under the 'government buildings' occupancy category was investigated through numerical analyses. To this end, a reference RC frame structure, initially designed in the study of Demir [11] in accordance with TEC-2018 was modeled numerically. Subsequently, the progressive collapse performance of these structures was assessed using a direct design methodology as outlined in the GSA-2016 [5] and UFC 4-023-03 [6] guidelines.

Three independent column removal scenarios were considered to simulate potential local failures. These scenarios were analyzed using the Nonlinear Dynamic Analysis Method, a part of the Alternate Path approach within the direct design framework. The inelastic behavior of the structural members was represented using a lumped plasticity model, with plastic hinges assigned to the member ends. The analyses were performed using SAP2000 [10], a widely used commercial FE software capable of both static and dynamic structural analysis. The findings indicate that the structure exhibited limited and localized damage, which was not disproportionate to the initial triggering failure.

Methodology

In this study, the progressive collapse performance of a seven-story reinforced concrete (RC) public building, designed in accordance with the Turkish Building Earthquake Code (TEC-2018), was numerically investigated using the Alternate Path (AP) method as prescribed by the GSA-2016 and UFC 4-023-03 guidelines. The analyses were conducted using the Nonlinear Dynamic (ND) analysis method within the SAP2000 finite element software. The nonlinear behavior of structural members was simulated using automatic plastic hinge assignments based on the lumped plasticity theory, with hinge properties derived from TEC-2018 material models. Geometric nonlinearity, incorporating P-Delta and large displacement effects, was also taken into account. The scenarios simulated the sudden loss of dual column pairs at corner (A1-A2), exterior edge (A3-A2), and interior (C3-C2) locations on the first and fourth stories. The building's performance was assessed by comparing the resulting plastic rotation demands against the damage acceptance criteria defined in TEC-2018.

Properties of the Designed Buildings

Within the scope of this study, the reference building's floor plan is presented in Figure 1. The total building height was set to 24.5 meters with 3.5 m in story height, corresponding to a seven-story configuration, to represent typical low-rise reinforced concrete structures. The occupancy category of "government buildings" was assigned to the structure, and medium soil conditions were assumed for the site location [11]. Dead, live, and snow loads acting on the structure were determined in accordance with the provisions of TS-498 [12].

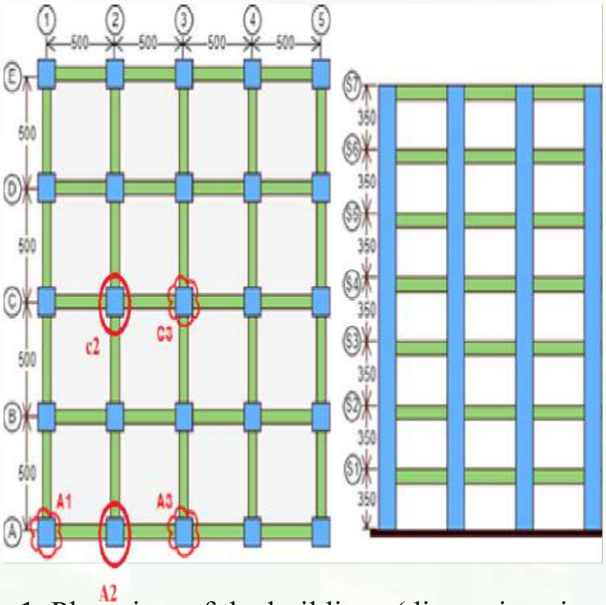


Figure 1. Plan view of the buildings (dimensions in cm) [11]

UFC 4-023-03 [6] and GSA-2016 [5] standards, all governmental buildings with three or more stories are required to meet the prescribed criteria. Both documents adopt a threat-independent approach, wherein the cause of the initiating event is not explicitly considered. UFC 4-023-03 [6] outlines three direct design methodologies: the Alternate Path (AP), Enhanced Local Resistance, and Tie Forces approaches. In contrast, GSA-2016 [5] employs only the Alternate Path method.

The AP approach—common to both guidelines—involves the hypothetical and independent removal of vertical load-bearing elements at selected locations in both the plan and elevation of the structure. The building must demonstrate the ability to span across the removed element without collapsing. The AP method allows for three types of analysis techniques: Linear Static (LS), Nonlinear Static (NS), and Nonlinear Dynamic (ND). While the LS and NS methods impose certain restrictions related to geometric regularity, the ND method is applicable to structures exhibiting geometric irregularities [4, 5].

Following this, the locations for the hypothetical removal of load-bearing elements are selected in accordance with the guidance provided in the standards. These locations typically include exterior columns situated at building corners, near the midpoints of both short and long façades, as well as selected interior columns. Additionally, columns located at points where there are significant changes in the building's plan geometry must also be considered for removal scenarios.

To satisfy the requirements of progressive collapse prevention, none of the structural elements may exceed their prescribed acceptance limits during the analysis. If the predicted structural response violates any of these limits, the building is deemed noncompliant with the progressive collapse criteria. In such cases, the structure must be redesigned or retrofitted to address the identified deficiencies [5], [6].

Numerical Modeling of the Buildings for Progressive Collapse Analysis

The progressive collapse assessment of the designed buildings was carried out using the Nonlinear Dynamic Analysis (ND) method within the Alternate Path (AP) direct design framework, as prescribed by both GSA-2016 [5] and UFC 4-023-03 [6]. For this purpose, a detailed three-dimensional finite element (FE) model was developed in SAP2000 [10], a commercial software widely used for static and dynamic analysis of structural systems. In the modeling process, beams and columns were represented using frame elements, while slab loads were distributed and transferred to the adjacent beam elements.

Two principal modeling strategies are commonly employed to simulate the post-yield inelastic behavior of structural load-bearing members: the *concentrated (lumped) plasticity model* and the *distributed plasticity model*. In the lumped plasticity approach, it is assumed that inelastic deformations are confined to discrete regions—typically at the ends of members—while the remaining portions of the element remain elastic. In this model, nonlinear behavior is represented by integrating plastic strain and curvature over a predefined hinge length. In contrast, the distributed plasticity model divides the cross-section of a structural member into numerous representative axial fibers that span either the entire member length or a designated hinge region (fiber hinge). Each fiber requires an explicitly defined stress–strain relationship. The overall axial force–deformation and biaxial moment–rotation responses of the member are then obtained by integrating the fiber behavior over the cross-section and multiplying by the corresponding hinge length [14]–[16].

It is well established that RC frame structures can resist disproportionate collapse by developing two critical load-resisting mechanisms: *Vierendeel (arching) action* and *catenary action*. In the present study, the lumped plasticity approach was adopted due to its ability to provide efficient and reliable simulation of structural response, lower computational costs, enable clear identification of plastic hinge formations, and support practical application in performance-based seismic evaluations.

In this study, the beam and column elements were modeled in SAP2000 using the concentrated plasticity approach. The software's automatic hinge definition capability was utilized to assign plastic hinge regions at the ends of the frame elements, where inelastic deformations are expected to localize. Within this framework, the material properties of concrete and reinforcing steel were defined in accordance with the specifications outlined in TEC-2018 [9].

SAP2000 automatically computed the hinge parameters, including yield moment, post-yield stiffness degradation, and damping characteristics. The nonlinear hinge behavior was modeled using the stress–strain relationships prescribed in TEC-2018 for both concrete and steel materials [9].

Initially, a nonlinear static analysis case was established to account for gravity loads combined according to Equation of $1.2DL + 0.5LL + 0.2S$ in UFC 4-023-03 [6], where DL denotes Dead Load, LL represents Live Load, and S corresponds to Snow Load. This load case served to determine the equilibrium forces acting on each removed column and was used as the initial condition for subsequent column removal simulations. Subsequently, the column element was removed from the structural model, and the corresponding equivalent column loads were applied as a new load case at the node located immediately above the removed column's base. This step effectively models the presence of the removed column within the building's load path.

Following this, a new load pattern was generated to apply the equivalent removed column loads with reversed signs, simulating the progressive removal of the column. A ramp function was utilized to incrementally apply this load pattern at the joint above the removed column during a nonlinear dynamic time-history analysis, thereby progressively eliminating the equivalent column loads [4, 5].

In accordance with the recommendation provided by UFC 4-023-03 [6], the duration of the ramp function used for column removal was selected to be less than one-tenth of the building's fundamental period. For the 7-story structure analyzed in this study, whose first natural period was determined as 1.56 seconds, the removal duration was accordingly taken as 0.15 seconds. Following the completion of the gravity load analysis and establishment of static equilibrium, the column removal was initiated at 0.5 seconds. To monitor the structure's residual vertical displacements after oscillation decayed, the total duration of the dynamic analysis was extended to 3 seconds. The nonlinear dynamic time history analysis was performed using the Direct Integration method. Rayleigh damping corresponding to 5% critical damping was defined based on the first two natural periods of the building. The Newmark time integration scheme was employed for time-stepping, with Gamma and Beta parameters set to 0.50 and 0.25, respectively. Furthermore, geometric nonlinearities were considered by enabling the P-Delta and Large Displacement options in the analysis software, thereby capturing potential catenary effects in the beams surrounding the removed column [11], [15].

In accordance with the column removal locations recommended by GSA-2016 [5] and UFC 4-023-03 [6], three distinct paired column removal scenarios were applied on the first and fourth stories of the modeled buildings. To assess the progressive collapse behavior, the following simulations were conducted independently: i) Removal of an exterior corner column along with its adjacent column (A1–A2), ii) Removal of a column positioned at the midspan of the outermost axis together with its adjacent column (A3–A2), iii) Removal of a central interior column and its adjacent column (C3–C2). The specific locations of the removed columns are depicted in Fig. 1.

The acceptance criteria for the damage states of reinforced concrete (RC) members were established in accordance with TEC-2018 [9], which defines permissible limits based on the lumped plasticity behavior model. The code categorizes damage into three levels: Limited Damage (LD), Moderate Damage (MD), and Severe Damage (SD). When evaluating RC members using the lumped plasticity approach, the allowable plastic rotation limits are specified in TEC-2018 [9] by the following equation (Eq. 2).

$$\theta_p^{GÖ} = \frac{2}{3}\left[(\phi_u - \phi_y) L_p \left(1 - 0.5 * \frac{L_p}{L_s}\right) + 4.5\, \phi_u d_b \right] \tag{2}$$

According to TEC-2018 [9], the formation of plastic hinges in structural members is prohibited under the Limited Damage (LD) performance criterion. Furthermore, within the framework of the lumped plasticity model, TEC-2018 [9] defines the Moderate Damage (MD) threshold as 75% of the Severe Damage (SD) limit, as expressed in Equation 3.

$$\theta_p^{(KH)} = 0.75\, \theta_p^{(GÖ)} \tag{3}$$

The computed damage state thresholds for the beam elements were incorporated into the material models of the sections and are summarized in Table 1.

Table 1. Acceptance criteria for the Beam members in terms of plastic rotations

Limited Damage (LD) [RAD]	Moderate Damage (MD) [RAD]	Severe Damage (SD) [RAD]
0	0.016539878	0.02205317

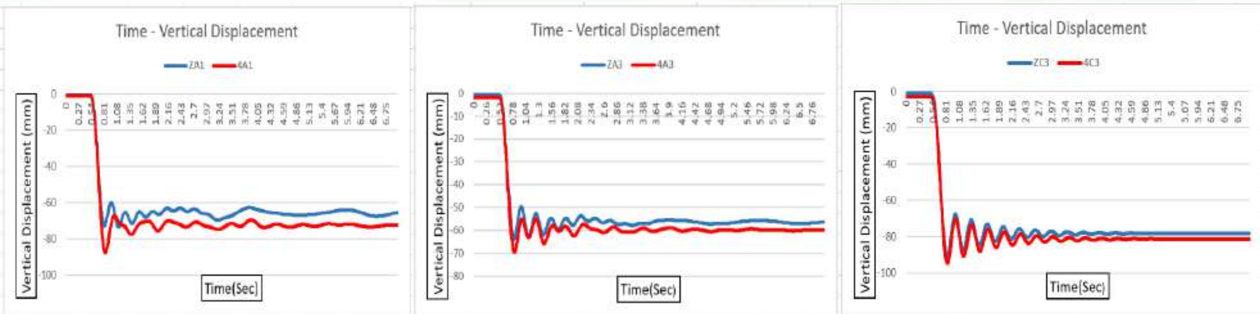
Results and Discussion

The vertical displacement time-history responses at the nodes above the removed columns for various column loss scenarios are illustrated in Fig. 2. The residual vertical displacements (u_r) at these nodes are summarized in Table 2. In the scenario involving the removal of the corner column and its adjacent column (A1 and A2) on the ground floor, permanent displacements of -72.79 mm and -66.24 mm were recorded, respectively. For the case where columns were removed on the fourth floor, permanent displacements increased to -87.66 mm and -73.97 mm. It was observed that the residual displacement for the fourth-floor column removal scenario exceeded that of the ground floor removal (Fig. 2a).

A similar trend was noted for the removal of the middle edge columns (A3 and A2), with residual displacements measured as -63.96 mm and -63.86 mm, and -69.68 mm and -69.49 mm, respectively (Fig. 2b). This behavior aligns with the well-established understanding that as the number of stories above the failure location increases, more beams engage in transferring loads from the removed column to adjacent members through Vierendeel (arching) and Catenary actions.

The most severe damage was observed in the scenario involving the removal of central column pairs on the inner axis (C3 and C2). Additionally, while the difference in residual displacement between ground and fourth-floor removal cases was pronounced in the corner column removal scenario (A1 and A2), this disparity decreased notably in the edge column removal case (A3 and A2) and was further diminished in the middle column removal scenario (C3 and C2) as shown in Fig. 2c.

The damage response of the load-bearing members was evaluated based on the acceptance criteria established in the previous section. The automatic plastic hinge formation patterns of the structural members are illustrated in Fig. 3. Due to the symmetry of the building plans and the similarity of results along the perpendicular axes, only elevation views corresponding to the axis where the column removal occurred are presented.



a) Removal of column pair A1&A2 at the 1st story and 4th story

b) Removal of column pair **A3&A2** at the 1st story and 4th story

c) Removal of column pair **C3&C2** at the 1st story and 4th story

Figure 2. The vertical displacement time-history of the node above the removed column

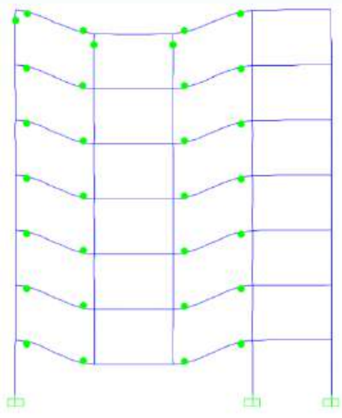
Table 2. Result of the residual vertical displacement value of the node above the removed column

Analyzed Scenario	Removed Column	u_r [mm]
Ground story scenario	A1&A2	-72.79
	A3&A2	-63.96
	C3&C2	-90.99
Fourth story scenario	A1&A2	-87.66
	A3&A2	-69.68
	C3&C2	-94.61

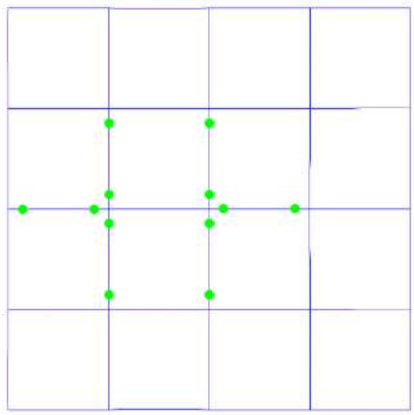
In the scenario involving the removal of the A1 and A2 column pair on the first story, Limited Damage (LD) was observed in beams adjacent to the removed columns as well as in the A3-B3 beam located at the roof level. For the fourth-story removal scenario, LD was detected in the beams spanning between B1-C1 and B2-C2. This variation is attributed to plan eccentricity, which diminishes the effectiveness of Vierendeel action in cases with fewer stories above the removal level (i.e., first-story removal) compared to scenarios with a greater number of overlying stories (i.e., fourth-story removal).

The progressive collapse analysis of the A3 and A2 column pair revealed distinct patterns of beam damage. In the first-story removal scenario, Limited Damage (LD) was confined to beams adjacent to the removed columns. Conversely, the fourth-story removal scenario resulted in LD within beams spanning B2–C2 and B3–C3. Comparisons of column damage further emphasized behavioral differences: the first-story scenario induced LD solely in the top-story Column A1, whereas the fourth-story scenario caused LD in both Columns A1 and A3. This disparity is attributed to plan eccentricity, which reduces the effectiveness of Vierendeel action in cases with fewer overlying stories (first-story removal) relative to those with more overlying stories (fourth-story removal).

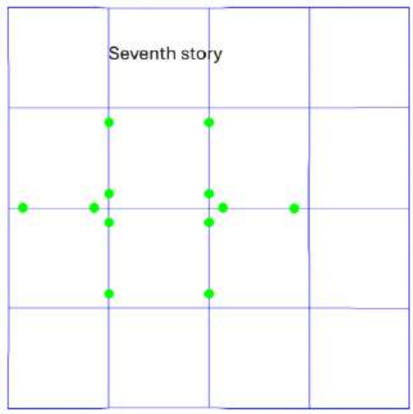
The progressive collapse analyses of the C3 and C2 column pair removal scenarios exhibited consistent outcomes. In both the first-story and fourth-story removal cases, Limited Damage (LD) was confined exclusively to beams adjacent to the removed columns, with no evidence of LD in other beam elements. Similarly, column damage patterns were uniform, with LD observed at the top-story Columns C1, C2, and C3 across both scenarios. This behavioral consistency is attributed to the relatively symmetrical plan configuration of the removed column pair, which allows for comparable Vierendeel action efficiency irrespective of the elevation at which the removal occurs, as depicted in Fig. 3.



a) Section view



b) Hinge pattern on the 7th-story plan for 1st-story column removal scenario



c) Hinge pattern on the 7th-story plan for 4th-story column removal scenario.

Figure 3. Removal of column pairs C3&C2 (Gray: no damage, green: limited damage, cyan: moderate damage, pink: severe damage (collapse prevention), red: failure (collapse))

Following the loss of one column pair on the first floors, the buildings exhibited varying damage states in their load-bearing members. The damage was primarily localized in elements directly connected to the removed columns. The most severe damage was observed in the scenario involving the removal of inner columns. This behavior can be attributed to two main factors: i) the beams spanning the removed inner columns are subjected to higher load demands due to the larger tributary areas associated with inner axis columns, necessitating greater load transfer to adjacent members; and ii) the gravity loads applied to outer axis columns are comparatively conservative, as these columns have smaller tributary areas and were designed with identical geometry and reinforcement details as the inner axis columns. It should be noted, however, that a more refined design approach for the outer axis columns—accounting for reduced cross-sectional dimensions and reinforcement—would likely result in significant damage and potential failure in these members as well [17].

Under TEC-2018 [9], government buildings are identified as having the highest progressive collapse risk when subjected to the simultaneous loss of an interior column pair. For public structures, such paired-column loss scenarios should not be dismissed as low-probability events; instead, they necessitate the integration of explicit and specific design strategies against extreme conditions, alongside conventional seismic design. Furthermore, existing government buildings must undergo comprehensive quantitative PC vulnerability assessments based on this identified risk profile.

Conclusion and Suggestions

In this study, the progressive collapse behavior of reinforced concrete (RC) frame structures, designed according to TEC-2018 [9] for the 'government buildings' occupancy class, was meticulously investigated. To achieve this, the Nonlinear Dynamic Analysis Method within the Alternate Path (AP) design philosophy, one of the direct design approaches outlined in GSA-2016 [5] and UFC 4-023-03 [6] guidelines, was employed. The plasticity of the structural load-bearing members was realistically simulated using nonlinear lumped plastic hinge models. Based on the analyses performed, the following significant findings were deduced:

- Damage resulting from the removal of column pairs was localized primarily to the members adjacent to the removed columns. The damage did not propagate to other structural elements, thereby preventing a total collapse of the building.
- The loss of interior column pairs resulted in the most severe damage among the examined scenarios.
- Beyond conventional seismic design methodologies, structures classified under the government buildings occupancy category require additional direct design strategies to enhance their progressive collapse resistance against extreme loading conditions.
- In the design of government buildings, the placement of critical facilities such as fuel tanks, boiler rooms, and generators must be established in advance. Potential failure modes for these essential systems should be proactively assessed, with corresponding evaluations of column positioning. The overall structural redundancy should then be verified through progressive collapse analyses to ensure system robustness under extreme events.
- Primary fire suppression and cooling system mains must be routed to avoid zones vulnerable to column loss. Additionally, these emergency systems should incorporate redundancy to maintain functionality during critical conditions.
- While the absence of a total progressive collapse indicates the building's structural integrity against complete failure, the observed -94.61 mm vertical displacement in the worst-case scenario is still significant enough to compromise non-structural elements. Such deformation could inflict damage upon critical utilities like electrical, water, and natural gas lines, thereby posing a direct threat to the safety and well-being of the occupants.

It is imperative to note that a singular column design has been employed in this study. It must be noted that real-world projects are likely to yield divergent designs and outcomes, necessitating consideration of varied contextual factors. Consequently, a more detailed design approach could better capture the structural response under corner and side column loss scenarios. Furthermore, existing buildings designed and constructed prior to the implementation of TEC-2018 [9] may exhibit an increased risk of progressive collapse due to reliance on earlier engineering standards and knowledge.

Therefore, particular emphasis should be placed on evaluating and enhancing the progressive collapse resistance of these buildings against potential catastrophic extreme events to mitigate human casualties and economic losses. To achieve a more comprehensive assessment of PC risk associated with government buildings designed according to TEC-2018 [9] or its earlier versions, further research encompassing a variety of structural systems, loading conditions, and soil characteristics is recommended.

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Integrating Spaces for Climate Change: The Beylikdüzü Example

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ABSTRACT

Beylikdüzü, a rapidly urbanizing and growing district in Istanbul, holds critical importance regarding the spatial impacts of climate change. This study, starting from an analysis of Beylikdüzü's current situation, proposes a holistic spatial planning model aiming to adapt to climate change. Key climatic risks such as urbanization and the urban heat island effect, as well as glacier melt and sea level rise, have been evaluated. Within the scope of the study, components of the spatial planning model, including the strengthening of Green Infrastructure, the integration of sustainable transportation networks, and the establishment of ecological corridors and carbon sinks, have been detailed. Through a focus area design, detailed analyses are presented for a selected region, leading to the development of a design approach that incorporates nature-based solutions tailored to Beylikdüzü's specific conditions. This model aims to enhance urban resilience, strengthen ecosystem services, and improve the local community's quality of life. Anticipated benefits include increased resistance to extreme weather events, biodiversity conservation, and reduced carbon emissions. The presented spatial planning model offers a concrete framework for Beylikdüzü's climate change adaptation process, while also serving as a guide for other regions with similar urbanization dynamics.

Key words: Climate Change, Green Infrastructure, Transportation Models, Carbon Emission Reduction, Ecological Corridor.

Introduction

Nowadays, global climate change poses serious threats to urban areas worldwide, exerting transformative effects on cities' physical, social, and economic structures. Combined with factors such as rapid urbanization, population growth, and the depletion of natural resources, climate change manifests itself in major metropolitan regions through consequences like the "urban heat island effect," extreme weather events, and rising sea levels. In this context, making cities resilient to the impacts of climate change is of critical importance for a sustainable future. Beylikdüzü, one of Istanbul's districts that has attracted attention in recent years with its notable planned urbanization trends, holds the potential to respond to this global challenge at a local level. Particularly with its rapid development and young population since the 2000s, Beylikdüzü offers an important case study for examining spatial planning approaches aimed at adapting to climate change. This study aims to develop a comprehensive spatial planning model for climate change adaptation in Beylikdüzü. This model seeks to provide a roadmap for a resilient and sustainable urban transformation, taking into account the district's existing urban structure, climatic risks, and potentials.

1. Current Status Analysis Of Beylikdüzü And İts Susceptibility To Climate Change Impacts:

In addition to analyzing Beylikdüzü's current urban form and environmental conditions, this section offers a multidimensional and in-depth assessment of the district's structural vulnerabilities to the complex and evolving impacts of climate change. As one of the rapidly urbanizing districts of Istanbul, Beylikdüzü has undergone substantial transformations since the early 2000s—driven largely by population influx, expanding housing demand, and shifts in land use policy. These transformations have not only reshaped the district's physical landscape but have also significantly altered its ecological balance, social structure, and infrastructural resilience. The cumulative effect of these changes has rendered Beylikdüzü increasingly susceptible to climate-induced hazards, such as extreme heat, flooding, and coastal impacts, which threaten both the built and natural environment.

This comprehensive vulnerability assessment draws upon a wide array of analytical tools and data sources, including spatial planning indicators remote sensing and geospatial analyses, socio-demographic profiling, and climate risk modeling. By synthesizing these datasets, the analysis constructs a granular and evidence-based profile of Beylikdüzü's exposure, sensitivity, and adaptive capacity in the face of escalating climate threats. This systemic understanding is critical for informing targeted interventions and for guiding future spatial planning efforts that aim to enhance urban resilience.

Among the most immediate and visible challenges confronting Beylikdüzü is the intensification of the Urban Heat Island (UHI) effect—a phenomenon exacerbated by the proliferation of heat-retaining surfaces and the reduction of natural cooling systems. The widespread replacement of vegetated land with impermeable materials such as concrete, asphalt, and masonry has led to a significant alteration of the local microclimate, especially in high-density residential and commercial zones. Surface heat accumulates throughout the day and is slowly released during nighttime hours, preventing thermal relief and increasing the occurrence of heat stress, particularly for vulnerable groups such as the elderly, children, and low-income communities with limited access to cooling infrastructure.

The deficiency of continuous vegetation cover, coupled with the spatial fragmentation of existing green areas, has critically undermined the district's ecological resilience. In many neighborhoods, greenery is either sparse, poorly maintained, or entirely absent. Furthermore, the lack of integrated ventilation corridors—linear pathways for wind circulation that can dissipate trapped heat—has led to the stagnation of hot air masses within the urban fabric. High Floor Area Ratios (FAR) in recently developed parcels have contributed to vertical heat accumulation and limited sky exposure, reducing the potential for passive cooling. Thermal imaging studies and land surface temperature analyses consistently reveal stark contrasts—often exceeding several degrees Celsius—between densely built-up areas and their greener counterparts. These patterns underline the urgent necessity for embedding climate-responsive design principles into both new developments and the retrofitting of existing urban spaces.

Beyond thermal risks, Beylikdüzü's geographical location along the Sea of Marmara introduces a set of long-term challenges associated with sea level rise and glacial melt, both of which are driven by anthropogenic climate change and accelerated polar ice sheet loss. As global mean sea levels continue to rise, largely due to the thermal expansion of seawater and the melting of glaciers and ice caps, low-lying coastal areas face increasing threats from permanent inundation, periodic tidal surges, and the intrusion of saline water into freshwater systems. For Beylikdüzü, these trends present a complex and multifaceted risk landscape, where environmental degradation converges with infrastructural fragility.

Topographic and hydrological analyses reveal that several neighborhoods situated along the district's coastline, particularly those characterized by flat terrain, poor drainage gradients, and limited protective infrastructure, are particularly susceptible to coastal flooding. The district's geological features—such as the presence of fault lines, clay-heavy soils, and low infiltration capacity—further aggravate the vulnerability of these zones. Inadequate or aging coastal protection structures, such as seawalls and drainage outfalls, are unlikely to withstand projected sea level rise scenarios beyond the mid-21st century, especially in the absence of significant reinforcement or redesign. Furthermore, the cumulative impacts of storm surges, rising groundwater levels, and land subsidence could lead to the degradation of critical infrastructure, including transportation corridors, utility networks, and residential foundations, posing long-term risks to human health, safety, and economic stability.

In tandem with these coastal threats, the increasing frequency, severity, and unpredictability of extreme precipitation events poses another escalating risk to Beylikdüzü's urban systems. According to region-specific climate projections, the Marmara Region—including Istanbul and its outer districts—is expected to experience a marked rise in both the intensity and irregularity of rainfall events. These developments are already observable, with recent years witnessing a surge in flash floods, sewer overflows, and road inundations. In Beylikdüzü, these events have exposed the limitations of existing stormwater management systems, which were designed under the assumption of historical rainfall averages that are no longer reliable in the context of a changing climate.

The district's drainage infrastructure—comprising underground pipe systems, surface canals, and culverts—lacks the redundancy and capacity required to manage high-volume rainfall within short durations. Compounding the problem is the extensive impervious surface coverage across the district, which prevents natural infiltration and accelerates surface runoff. Without sufficient blue-green buffer zones—such as wetlands, detention basins, and vegetated swales—the district has limited absorptive capacity to delay or divert stormwater flow. This has resulted not only in recurrent property damage and mobility disruption, but also in the contamination of water bodies through untreated runoff, which carries sediments, oils, heavy metals, and other pollutants from urban surfaces.

In light of these interacting vulnerabilities, there is an urgent and non-negotiable need to transition toward hydrologically resilient urban design, where water is treated as a fundamental driver of urban form and function. This entails the adoption of integrated stormwater management practices, the expansion of green infrastructure to slow and filter runoff, the retrofitting of existing grey infrastructure with adaptive features, and the reconfiguration of urban open spaces to enhance water retention. Without such forward-thinking and evidence-based planning interventions, Beylikdüzü risks entering a cycle of recurrent climate-induced disruptions that will undermine both its environmental sustainability and its social and economic vitality.

2. Components of Beylikdüzü Climate Change Adaptation Spatial Planning Model:

This section articulates the conceptual and operational pillars of the proposed spatial planning model, which aims to foster climate resilience in Beylikdüzü through integrated, multidisciplinary approaches. Rather than offering a rigid or prescriptive template, the model is designed as a dynamic and adaptable planning framework, capable of responding to the district's unique environmental characteristics, socio-demographic shifts, and long-term urban development trends. By embracing a holistic planning philosophy, the model integrates diverse disciplinary fields—including ecosystem-based adaptation (EbA), urban climatology, hydrology, landscape ecology, sustainable mobility, and participatory governance—to guide decision-making processes and spatial interventions that promote ecological balance and climate resilience.

At the core of the model lies the enhancement and reinforcement of green infrastructure systems, which are recognized not only for their environmental benefits but also for their socio-spatial co-benefits. Green infrastructure is conceptualized as a multifunctional system that serves critical roles in urban climate regulation, biodiversity conservation, public health, flood management, and social cohesion. The first step involves a comprehensive inventory and mapping of existing green assets, including parks, urban woodlands, stream corridors, and vegetated land parcels. However, preservation alone is insufficient; active expansion and integration of these green elements into the urban fabric is essential. This includes the transformation of vacant plots, degraded brownfields, and interstitial spaces into accessible green zones. Moreover, vertical greening technologies such as living walls, façade-integrated vegetation, and green roofs should be mainstreamed across both public and private buildings to enhance thermal comfort and reduce heat accumulation in densely built environments.

Equally important is the greening of transport corridors and public rights-of-way, particularly in heat-stressed or impermeable zones. Strategic street tree planting, with species selected based on canopy coverage, drought resistance, and CO_2 sequestration capacity, can dramatically improve microclimates, promote walkability, and reduce surface temperatures. When implemented in tandem with cool roofs, shaded bus stops, and permeable sidewalks, these interventions offer cumulative mitigation benefits while enhancing the livability and visual identity of urban streetscapes.

Another foundational dimension of the model is the transition toward sustainable, inclusive, and low-carbon transportation systems. In the context of Beylikdüzü's expanding population and increasing motorization trends, climate-resilient mobility strategies must prioritize modal shift, emissions reduction, and equitable access. The planning model emphasizes the establishment of safe, continuous, and accessible bicycle lanes, which are seamlessly connected to public transit nodes and major activity centers. The improvement of pedestrian infrastructure—including widened and shaded sidewalks, universal design features, and pedestrianized streets in commercial hubs—can significantly promote non-motorized mobility and reduce dependence on private vehicles.

Moreover, integrated transit systems should be developed through the synchronization of metro, bus, minibus, and ferry services, ensuring spatial and temporal coordination to minimize transfer times and service gaps. Public transportation fleets must gradually transition to low-emission or zero-emission vehicles, powered by renewable energy sources such as solar and wind. The establishment of electric vehicle (EV) charging networks, smart mobility hubs, and bike-sharing stations further complements this goal. These transportation investments should be implemented with a strong commitment to climate justice, ensuring that marginalized or underserved communities gain equitable access to clean and efficient mobility systems.

An additional pillar of the model focuses on the creation of urban ecological corridors and carbon sink networks. Rapid urban development has caused the fragmentation of natural habitats within Beylikdüzü, leading to ecological isolation, loss of biodiversity, and weakened ecosystem services. The planning model proposes a reconnection strategy by identifying and restoring critical habitat patches—such as small forests, stream banks, and agricultural remnants—and linking them through greenways, bioswales, and landscape buffers. These ecological corridors not only allow for wildlife movement and gene flow, but also contribute to urban cooling, stormwater filtration, and air purification. Urban carbon sinks, including reforested areas, community gardens, green campuses, and urban orchards, serve as natural mechanisms for carbon capture and sequestration. These green zones also hold educational and recreational value, encouraging environmental stewardship and place-based learning among residents.

Lastly, the model strongly advocates for the integration of blue-green infrastructure (BGI) and Water Sensitive Urban Design (WSUD) approaches. Traditional grey infrastructure systems—comprising underground culverts, pipes, and storm drains—are increasingly inadequate in the face of more frequent and intense rainfall events projected under climate change scenarios. Instead, hybrid infrastructure that combines natural water retention features with engineered drainage solutions is prioritized. The incorporation of rain gardens, bioswales, infiltration basins, wetlands, permeable paving, and green roofs helps mitigate surface runoff, reduce peak discharge rates, and enhance water quality. Additionally, rainwater harvesting systems and greywater reuse technologies can be deployed

at the building and neighborhood scale, reducing dependency on potable water supplies and enhancing urban water cycle efficiency.

WSUD is underpinned by a systems-thinking perspective, in which the entire hydrological cycle is embedded into urban planning and design. Instead of viewing rainwater as a hazard or waste product, the model promotes its capture, treatment, storage, and reuse as a valuable urban resource. These strategies not only enhance urban flood resilience, but also foster ecological restoration, groundwater recharge, and climate-responsive landscaping.

In summary, the spatial planning model proposed for Beylikdüzü is a forward-thinking, flexible, and interdisciplinary roadmap toward long-term climate adaptation. By simultaneously addressing green and blue infrastructure, mobility, energy, land use, and ecosystem connectivity, it lays the groundwork for a more resilient, inclusive, and sustainable urban future.

3. Focus Area Design and Implementation Approaches

To illustrate the applicability and adaptability of the proposed spatial planning model, this section delves into its practical implementation through a series of design interventions across selected focus areas within the Beylikdüzü district. These pilot zones act as real-world laboratories for testing climate resilience strategies, allowing for iterative learning, community engagement, and the refinement of scalable models that can be extended to other parts of the district, Istanbul, or even comparable metropolitan areas facing similar climate risks. The overarching goal is not only to introduce context-sensitive solutions but also to build institutional and societal capacity for adaptive urban governance.

The identification and selection of these focus areas are grounded in a multi-criteria decision-making process that incorporates spatial, environmental, social, and infrastructural indicators. Variables such as surface temperature anomalies, flood hazard zones, topographic vulnerability, population density, poverty indices, green space accessibility, and infrastructure deficiency levels are synthesized using GIS-based spatial overlays and weighted analyses. Furthermore, local knowledge is actively integrated through participatory mapping exercises, neighborhood-scale site visits, and deliberative workshops with residents, municipal officials, and civil society representatives. This hybrid approach ensures that the selection reflects both technical assessments and lived experiences, leading to more inclusive and responsive planning decisions.

In each of the selected zones, a customized suite of interventions is designed based on the principles of climate-sensitive urbanism, regenerative design, and socio-ecological integration. Physical interventions are aligned with microclimatic data and hydrological modeling to ensure functional outcomes under projected climate scenarios. For instance, in flood-prone areas with compacted, impervious soils and insufficient drainage, bioswales and rain gardens are deployed not merely as aesthetic elements but as hydrological infrastructure capable of capturing, filtering, and slowly releasing stormwater. In parallel, streetscapes are reimagined with the integration of permeable pavements that allow for groundwater recharge, alongside canopy trees that provide evapotranspirative cooling and protection from the urban heat island (UHI) effect.

Public spaces, particularly those in socio-economically vulnerable neighborhoods, are restructured to serve as climate shelters. These spaces are outfitted with tree-lined pedestrian corridors, shaded rest areas, and water features that support thermal comfort and social cohesion. Building-scale interventions are also included: façades are upgraded with reflective coatings, insulation layers, and passive ventilation features.

Roofs are transformed into multifunctional surfaces, incorporating photovoltaic panels, green roofs, or rainwater collection systems depending on the site-specific requirements and feasibility. Native and drought-tolerant plant species are selected across all interventions to enhance biodiversity, reduce irrigation needs, and strengthen ecosystem services.

A defining characteristic of these design strategies is their reliance on nature-based solutions (NBS). In dense urban blocks with limited ground-level space, vertical gardens and modular green wall systems are employed to extend the ecological footprint vertically, simultaneously improving air quality and offering visual relief. In vacant or underused parcels—many of which are located in degraded or marginalized areas—constructed wetlands, pocket parks, and multifunctional rain gardens are introduced to mitigate flood risk while creating ecological and social value. These spaces double as community hubs, featuring interpretive signage, educational stations, and collaborative stewardship models such as school-led planting programs and neighborhood “green committees.”

The implementation framework also emphasizes the importance of co-benefits generated by these interventions. Mental and physical health improvements, opportunities for informal education, increases in property values, job creation in green infrastructure maintenance, and heightened social resilience are carefully tracked as part of a long-term monitoring strategy. These metrics feed into adaptive management systems that allow for real-time adjustments based on environmental feedback and community satisfaction.

Ultimately, the pilot areas are not intended to be isolated exemplars but catalytic zones for district-wide transformation. Their design and implementation processes are documented and institutionalized through guidelines, toolkits, and policy briefs, enabling replication and upscaling. Partnerships with academic institutions, NGOs, and private sector actors are fostered to ensure technical robustness, financial sustainability, and broad-based ownership. In this way, the spatial planning model becomes not only a technical roadmap for climate adaptation but also a vehicle for ecological urbanism, participatory governance, and socio-environmental justice in Beylikdüzü.

Conclusion

This study positions spatial planning as a pivotal tool for climate change adaptation in rapidly urbanizing contexts, using Beylikdüzü as a representative case. The Climate Change Adaptation Spatial Planning Model developed here offers a systemic, locally grounded, and ecologically informed framework to enhance urban resilience in the face of intensifying climatic threats. Through a combination of strategic land use planning, infrastructure transformation, and nature-based interventions, the model addresses multiple risk vectors—urban heat, sea level rise, flooding, and ecosystem fragmentation—in an integrated manner.

By placing emphasis on green infrastructure, sustainable transportation, ecological networks, and water-sensitive urbanism, the model bridges the gap between environmental sustainability and urban livability. It foregrounds nature-based solutions not as ancillary or decorative elements, but as foundational components of urban adaptation and regeneration. Moreover, the model advocates for inclusive governance, participatory design, and interdisciplinary collaboration, recognizing that climate resilience is not solely a technical challenge but a social and institutional one.

Ultimately, the Beylikdüzü case offers a replicable and scalable approach for cities seeking to future-proof themselves against climate uncertainty. It provides not only a planning toolset but a new urban vision—one that is regenerative, adaptive, and in harmony with natural systems. The integration of this model into planning policies, development codes, and community practices can catalyze a transition toward climate-resilient urbanism in Istanbul and beyond.

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An Examination of Eskişehir City Center in the Context of Social Innovation and Urban Resilience

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ABSTRACT

This study investigates the city center of Eskişehir within the integrated framework of social innovation and urban resilience, two interrelated concepts increasingly emphasized in addressing contemporary urban challenges such as climate change, rapid urbanization, migration, and socio-economic inequalities. The research adopts a mixed-methods approach, combining a comprehensive literature review, a structured survey administered to 150 residents aged 18 and above, and semi-structured interviews with 15 stakeholders representing municipal authorities, academia, civil society, the private sector, and neighborhood administrations. The quantitative results reveal that 52% of respondents are familiar with the concept of social innovation, 60% are aware of urban resilience, and 68% express willingness to participate in local initiatives. Qualitative analysis highlights key local practices, including municipal youth centers, smart city applications, digital public services, urban gardening projects, and cultural solidarity programs, all of which contribute to both social cohesion and adaptive urban capacity.

The historical trajectory of Eskişehir's development in these domains mirrors Türkiye's broader evolution: from small-scale, problem-oriented projects in the early 2000s, through institutionalized academic and municipal collaborations in the 2010s, to sustainability- and technology-driven initiatives in the 2020s. The city's young, university-oriented demographic structure has acted as a catalyst for innovation, yet institutionalization, systematic policy integration, and long-term evaluation mechanisms remain areas requiring reinforcement.

Findings underscore that social innovation and urban resilience are mutually reinforcing processes: social innovation generates participatory and creative solutions that strengthen a city's resilience to environmental, economic, and social risks, while resilience-oriented planning ensures the sustainability of these innovations. Policy recommendations include establishing dedicated municipal units for social innovation, expanding participatory governance through digital platforms, prioritizing climate adaptation strategies, and fostering multi-stakeholder collaboration. The Eskişehir case demonstrates how mid-sized cities can serve as experimental and replicable models for inclusive, adaptive, and sustainable urban futures.

Key words: Social innovation, Urban resilience, Eskişehir, Participatory governance, Sustainable cities

Introduction

Cities today face a wide range of interrelated challenges including climate change, rapid urbanization, migration, and socio-economic inequality. These complexities demand innovative, inclusive strategies beyond traditional planning models. Social innovation emerges here as a meaningful approach that fosters creative, participatory, and sustainable solutions to social problems [1,2]. It aims to increase well-being through new services, processes, or collaborative models that generate societal value [3].

Figure 1. Social Innovation Process

In this study, the social innovation process specific to Eskişehir is examined through four main stages: problem identification, idea development, solution implementation, and impact creation. At each stage, references are made to both the general literature and local examples from Eskişehir and Türkiye.

1. Problem Identification

Social innovation begins with the identification of societal needs that require resolution [4].

In Türkiye, studies within public institutions indicate that especially public actors often lack a full understanding of the concept of social innovation, making it difficult to clearly define problems [5].
In Eskişehir, problems are identified through quantitative and qualitative analyses in areas such as urban design, transportation, and environmental issues. For example, engineering student clubs at Eskişehir Technical University have focused on developing solutions to local problems [6].

2. Idea Development
Once the problems are identified, new and innovative ideas are generated. In Türkiye, such ideas often emerge through public–institution collaborations, especially within the framework of social entrepreneurship models [5].
In Eskişehir, stakeholders from diverse fields (university, civil society, and municipality) collaborate on urban design projects (e.g., the search for identity in the Hamamyolu district) and local initiatives [7].

3. Solution Implementation
The implementation phase begins once ideas are translated into action. In Türkiye, a lack of regulatory frameworks within public institutions slows down progress, even though pilot projects are often initiated [4].
In Eskişehir, student engineering teams such as the ESTU Solar Team and UAV Team develop technological solutions to local problems and actively conduct prototyping and testing processes [8].

4. Impact Creation
When social innovation solutions are implemented, their impact on target populations is measured and evaluated. In Türkiye, social innovation is often framed under social entrepreneurship, which tends to have limited influence on regional welfare [5].
In contrast, Eskişehir demonstrates that student-led projects can achieve commercialization and generate social impact through participation in competitions and partnerships with industry, thereby contributing to both social welfare and economic value [9].

This framework illustrates how the social innovation process unfolds in Eskişehir and enables a comparative analysis with Türkiye's broader institutional challenges.
According to Moulaert et al. [10], social innovation encompasses three main dimensions: designing solutions for unmet needs, enhancing civic engagement, and empowering individuals socio-politically. Particularly, the active participation of youth strengthens this dynamic, contributing to both individual and collective well-being [11].

Social Innovation Studies in Türkiye:
Social innovation in Türkiye has gained significant traction, especially since the early 2000s. Work in this field is primarily carried out by universities, non-governmental organizations (NGOs), and development agencies. Social innovation aims to generate new and effective solutions to social, environmental, and economic problems faced by society. In academic literature, the concept is used to describe innovative approaches in areas such as poverty, education, health, environmental issues, and employment.
2000s: This period marked the beginning of discussions on social innovation in academic and practical fields in Türkiye. European Union (EU) projects and international collaborations, in particular, raised awareness of social innovation. For instance, the EU's "Social Inclusion and Employment" themed programs supported in-

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novative projects aimed at combating poverty and integrating disadvantaged groups into society [12].
2010s: The concept of social innovation matured further during this decade. Universities began establishing social innovation centers and labs, leading to an increase in research and theses in the field. Various development agencies in Türkiye also initiated calls for social innovation-themed projects. A significant development during this period was the emergence of social enterprises focusing on youth and women's employment, refugee integration, and rural development. These ventures prioritize social benefit over the classic commercial business model [13].
2020s: Social innovation is now being addressed in a more systematic and widespread manner. The Covid-19 pandemic, in particular, accelerated digitalization and new social innovation models in areas such as healthcare, education, and social services. Collaboration between public institutions, the private sector, and NGOs has increased, strengthening the social innovation ecosystem.
Social Innovation Studies in Eskişehir
Due to its high concentration of universities and young population, Eskişehir is one of the leading cities in the field of social innovation. Work in this area is conducted through the collaboration of universities, local governments, and civil society.
2000s: During this period, social innovation studies in Eskişehir began with small-scale projects targeting disadvantaged groups. Local governments and NGOs carried out vocational training and social integration projects for women and individuals with disabilities.
2010s: The social innovation ecosystem in Eskişehir developed further in this decade. Academic research and projects on social innovation were conducted in various faculties at Eskişehir Osmangazi University (ESOGÜ) and Anadolu University. Innovative approaches, particularly on topics like urban renewal and the preservation of cultural heritage, emerged during this time [14]. For example, projects like the "City Memory Project" are examples of social innovation aimed at preserving and disseminating local history and culture on digital platforms.
2020s: Social innovation in Eskişehir has shifted toward technology and sustainability-focused projects. Smart city applications, eco-friendly transportation solutions, and digital platforms that enhance youth participation have come to the fore. Social innovation projects carried out in Eskişehir can be implemented and scaled more easily due to the city's dynamic structure.
Urban Resilience Studies in Türkiye
The concept of urban resilience has gained increasing importance in Türkiye, especially after the 1999 Gölcük earthquake. The term refers to a city's ability to prepare for, recover quickly from, and adapt to shocks and stresses such as natural disasters, climate change, and economic crises.
Urban resilience studies in Türkiye primarily focus on the following topics:
Disaster Management and Risk Reduction: Taking structural and non-structural measures in high-seismic-risk areas, emergency planning, and raising public awareness.
Climate Change and Environmental Sustainability: Increasing green spaces, water management, energy efficiency, and reducing the urban heat island effect.
Economic and Social Resilience: Ensuring economic diversity, strengthening social cohesion, and protecting disadvantaged groups.
Work in this area is conducted by the Ministry of Environment, Urbanisation and Climate Change, AFAD (Disaster and Emergency Management Authority), local governments, and universities. "Urban Transformation Projects" are one of the most important policies aimed at increasing urban resilience. However, the social and economic impacts of these projects are frequently debated in academic circles [15].
Urban Resilience Studies in Eskişehir:
Eskişehir, while a city with seismic risk due to its geological location, is also facing the effects of rapid urbanization and climate change. Therefore, urban resilience studies hold a significant place on the city's planning agenda.
1990s and 2000s: Work during this period focused more on seismic risk. Issues such as building inspection, identification of high-risk structures, and revision of zoning plans became a priority. After the 1999 earthqua-

ke, awareness regarding the seismic resistance of the building stock also increased in Eskişehir.
2010s: The concept of urban resilience expanded beyond just earthquakes to be addressed from a broader perspective. During this decade, Eskişehir Metropolitan Municipality and district municipalities focused on "Smart City" and "Sustainable City" projects. The regulation of the Porsuk River's surroundings and the identification of urban renewal areas are examples of work aimed at increasing environmental and social resilience [16]. The urban planning departments of Anadolu University and Eskişehir Technical University have conducted academic research on urban resilience.
2020s: In this period, Eskişehir addresses urban resilience in the context of climate change and social integration. Projects that enhance environmental resilience, such as increasing green spaces, expanding bike paths, and improving public transportation, have gained momentum. Additionally, social resilience work aimed at strengthening the social cohesion of disadvantaged groups living in different parts of the city is also being carried out.

Methodology

A mixed-methods approach was used to explore Eskişehir's landscape of social innovation and urban resilience. The research process consisted of three main phases: a literature review, a survey, and semistructured interviews.

In the first phase, both national and international academic literature was reviewed. A comparative analysis was conducted between social innovation practices in Turkey and policy frameworks developed by the European Union [3,17].

In the second phase, a survey was conducted with 150 participants aged 18 and over, selected through random sampling within the city center of Eskişehir. The survey instrument measured respondents' awareness of social innovation, perceptions of participation, and views on urban resilience.

In the third phase, semi-structured interviews were held with 15 individuals representing five stakeholder groups: municipal officials, non-governmental organizations, academics, private sector managers, and neighborhood heads. The qualitative data gathered from these interviews were analyzed thematically using coding techniques, as outlined by Neuman [18].

Main Results and Discussion

The findings indicate that Eskişehir possesses significant potential in advancing social innovation and strengthening urban resilience. According to the survey results, 68% of participants expressed openness to innovative urban solutions, and 52% reported being familiar with the concept of social innovation.

Table 1. Awareness of Participants Regarding Social Innovation

Awareness Level	Percentage (%)
Heard of the term "Social Innovation"	52
Aware of Urban Resilience Concepts	60
Willingness to Participate in Local Projects	68

Qualitative findings from the interviews reveal that municipal youth centers, digital public services, urban gardening initiatives, and cultural solidarity programs are among the most impactful examples of both social innovation and resilience practices in Eskişehir [1,2].

Theme	**Indicators / Data**
Health	- Access to healthcare services - Public health protection initiatives - Preventive measures against infectious diseases - Anti-drug programs
Education	- Accessibility of educational services - Public education programs and community courses
Gender Equality	- Measures against discrimination toward women and girls - Equal participation of women in economic and social life - Number of female staff in the municipality - Number of female members in the municipal council
Disadvantaged Groups	- Improving quality of life for the elderly - Inclusion of individuals with disabilities in social life - Activities targeting youth and children - Integration policies for migrants and asylum seekers - Animal protection practices

Table 2. Themes and Indicators Representing the Social-Governance Dimension of Sustainable Urban Development

In the case of Eskişehir, community-based initiatives are notably strong. However, these efforts should be more systematically integrated into city-wide policies and supported through institutional mechanisms. According to the OECD's four-dimensional model of resilience (economy, environment, society, and governance), Eskişehir's urban policies must pursue a more balanced and data-driven approach to effectively increase resilience [19].

The research conducted reveals a chronological evolution of studies in social innovation and urban resilience in Türkiye and, specifically, in Eskişehir.

Findings from Türkiye:

Social Innovation: The concept of social innovation, which gained prominence in the 2000s primarily through international funds and EU projects, acquired an institutional dimension in the 2010s with the establishment of university centers and the proliferation of social enterprises. In the 2020s, influenced by global crises like the pandemic, the ecosystem has shifted towards generating digital and systemic solutions. The studies were found to address fundamental social issues such as poverty, employment, and the integration of disadvantaged groups

Urban Resilience: The 1999 Gölcük earthquake marked the starting point for the concept of urban resilience in Türkiye. Initially, the focus was on strengthening physical infrastructure against earthquakes, but this approach has gradually expanded to include broader risks such as climate change, economic shocks, and social cohesion. Urban Transformation Projects, in particular, have emerged as the most central policy tool for increasing urban resilience, though their social impacts have become a subject of academic debate.

Findings from Eskişehir:

Social Innovation: Eskişehir, with its young and dynamic population, provides fertile ground for social innovation work. The process, which began with local-scale social aid and education projects in the 2000s, combined

with the academic accumulation of universities in the 2010s to produce concrete innovation examples like the "City Memory Project." In the 2020s, a trend towards smart city technologies and sustainability-focused projects has been observed.
Urban Resilience: Urban resilience studies in the city initially began with structural measures to address seismic risk. In the 2010s, the concept of resilience gained an environmental dimension with urban renewal and green space projects around the Porsuk River. Today, a holistic approach is being adopted to combat the effects of climate change, with projects supporting bicycle paths, public transport improvements, and social integration.

Conclusion

This study highlights the strategic importance of integrating social innovation and urban resilience into urban development agendas. Although initiatives observed in Eskişehir are promising, their long-term impact will depend on their institutionalization and the development of systematic monitoring and evaluation mechanisms.

The following key recommendations have been identified based on the research findings:

1. Municipalities should establish dedicated units for social innovation, particularly in the fields of youth, education, environment, and public health.
2. Participatory urban governance should be enhanced through digital platforms that enable meaningful citizen engagement in decision-making processes [20].
3. Strong collaborations between academia, municipalities, and civil society organizations should be encouraged to tailor social innovation practices to local needs.
4. Urban resilience planning should prioritize themes such as climate adaptation, crisis response, green infrastructure, and the reduction of social inequalities [19].
5. Awareness campaigns, training programs, and incentive systems should be developed to foster a widespread culture of innovation.

These recommendations can serve not only Eskişehir but also other cities with similar socio-economic and cultural characteristics. The integration of social innovation and resilience is essential for building inclusive, adaptive, and sustainable urban futures.

Based on these findings, it is concluded that studies in both social innovation and urban resilience in Türkiye have evolved from a reactive and problem-focused approach to a proactive and systemic one.
Conceptual Integration: Social innovation and urban resilience are complementary and mutually reinforcing concepts. Social innovation has the potential to generate creative solutions that enhance a city's resilience against environmental, economic, and social risks.
Stakeholder Collaboration: The success of initiatives in both fields is critically dependent on the existence of a strong collaborative ecosystem among public institutions, universities, non-governmental organizations, and the private sector.
Eskişehir as a Case Study: Eskişehir has assumed a pioneering role in social innovation and urban resilience work, thanks to its high concentration of universities and the dynamism of its young population. This highlights the importance of university-city cooperation in translating academic knowledge into practical applications.
Necessity of a Holistic Approach: For cities to be resilient not only against physical disasters but also against complex and multidimensional challenges such as climate change, migration, and economic crises in the future, a holistic urban management model that integrates social, environmental, and economic dimensions must be adopted.

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Resilient Cities and Sustainable Future: Youngsters Discuss Future of the Cities

The Role of Agrivoltaic Systems in Rural Development in Türkiye: An Eskişehir-Centred Assessment

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ABSTRACT

Agrophotovoltaic (APV) systems represent an innovative approach that enables simultaneous energy generation and crop cultivation on agricultural land. This study examines the potential of APV systems for rural development, focusing on the case of Eskişehir, Türkiye, through a qualitative research design.

Rural areas in Türkiye face sustainability challenges due to climate change, declining water resources, and reliance on traditional farming methods. Integrating renewable energy into agriculture offers opportunities to enhance energy independence and improve agricultural productivity. By combining solar power generation with ongoing farming activities, APV systems increase land-use efficiency, generate additional income for farmers, and improve microclimatic conditions.

The research employed semi-structured, in-depth interviews with 14 participants: farmers (n=7), agricultural advisors (n=3), energy sector representatives (n=2), and local government officials (n=2). Data were analyzed thematically, identifying four main themes: energy independence, water management, agricultural productivity, and implementation barriers.

Findings indicate an overall positive attitude toward APV systems among stakeholders. Farmers emphasized reductions in energy and irrigation costs and improvements in crop yields as key advantages. However, high initial investment costs, regulatory gaps, and limited access to technical knowledge were cited as major obstacles.

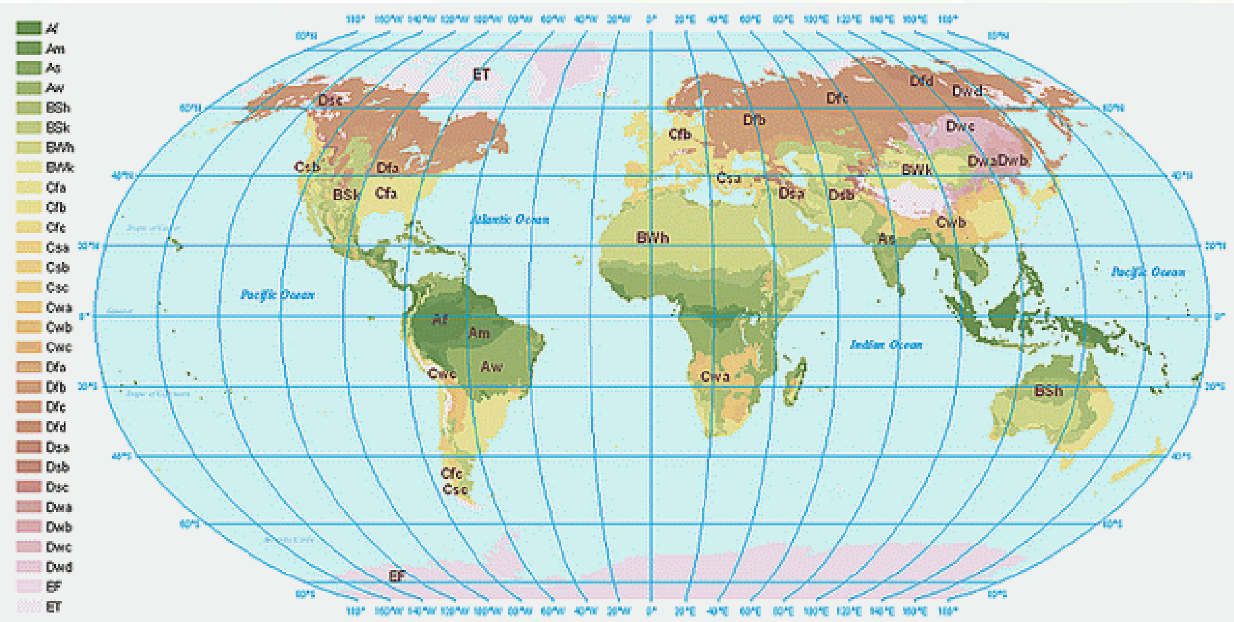
The results suggest that APV systems could strengthen agricultural resilience in Eskişehir by mitigating the effects of intense summer solar radiation and increasing drought risks, while enabling dual-income models through electricity generation. Successful implementation would require careful site selection of marginal lands, elevated structures compatible with agricultural operations, crop–shading alignment, early compliance with planning and permitting processes, and cooperative or self-consumption–oriented financing models. Policy adjustments and targeted training programs are essential to overcoming the identified barriers, positioning APV systems as a comprehensive rural development tool that supports both sustainable agriculture and energy transition in the region.

Key words: Rural Areas, Development, Agrivoltaic Systems, Eskişehir

Introduction

Eskişehir is located in the northwestern part of Central Anatolia between 29–32°E longitude and 39–40°N latitude. It is bordered by Afyonkarahisar's Emirdağ and İhsaniye districts to the south, Konya's Yunak district to the southeast, Ankara's Polatlı, Nallıhan, and Beypazarı districts to the east, Bolu's Göynük district to the northwest, and Bilecik's Gölpazarı, Söğüt, and Bozüyük districts as well as Kütahya to the west. Covering 13,652 km²—1.8% of Türkiye's total territory—Eskişehir ranks 14th among 81 provinces. According to 2021 Turkish Statistical Institute (TÜİK) data, the population is 898,369, with a density of 65.8 inhabitants per km² (1).

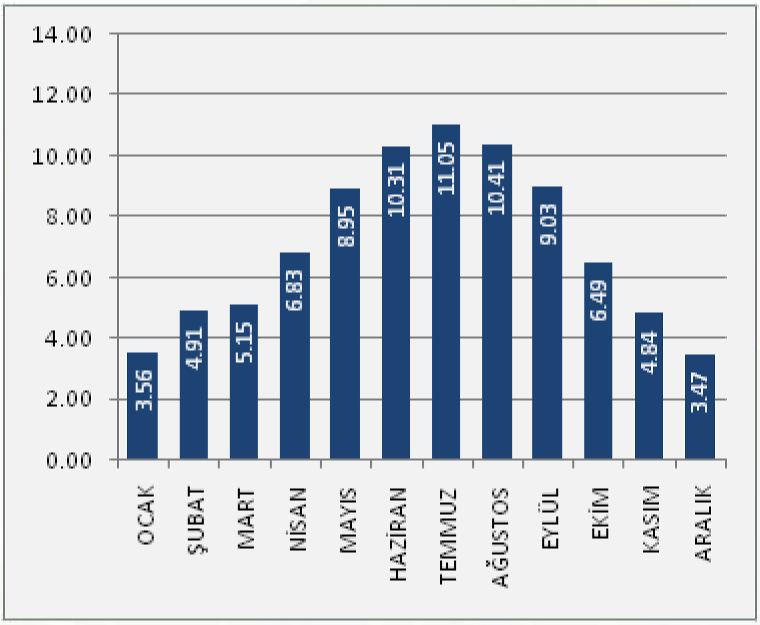
Topographically, the province consists of the plains of the Sakarya and Porsuk river basins, enclosed by the Bozdağ–Sündiken Mountains to the north and the Türkmen Mountain, Yazılıkaya Plateau, and Emirdağ to the west and south. The climate is semi-arid, with high agricultural water demand but limited water availability (2). Influenced by Central Anatolian, Western Black Sea, and Mediterranean climatic zones, Eskişehir experiences an average annual temperature of 10.9°C. January is the coldest month, and summers show Mediterranean-type drought characteristics. Annual precipitation averages 363.3 mm, with the highest monthly rainfall in May and December and the lowest in August (2).



Visual 1 Climate Classification

The concept of agrivoltaics (AV)—dual use of farmland for both photovoltaic (PV) electricity generation and agricultural production—was first introduced by Goetzberger and Zastrow in 1982 (3). Although the concept emerged over 40 years ago, the term and recognition of its potential have become more prominent only in recent decades (4). PV technology, which converts sunlight directly into electricity, has advanced in efficiency and reduced in cost since the 1970s, positioning solar energy as a leading renewable source globally and for Türkiye, which has an average annual solar radiation of 1,527.46 kWh/m² and 2,741 hours of sunshine (5).

In Eskişehir, annual solar radiation ranges between 1,500–1,650 kWh/m², with peak sunshine hours exceeding 10 hours per day in July. Sivrihisar district shows similar values (1,450–1,600 kWh/m²) and distinct seasonal variations in daylight length (6). This solar potential supports the integration of PV into agricultural systems. Elevated-panel AV systems allow the continued use of mechanised farming beneath, enabling sustainable food production while generating renewable energy (7).



Graph. 1 Sivrihisar Sunshine Duration (hours) (6)

Agrivoltaic Systems in the Global and Local Context

Agrivoltaic systems are particularly relevant in the context of global climate change, which has reduced global total factor productivity in agriculture by approximately 21% since 1961 (8). Projections indicate that by 2030, global demand for food, energy, and water will increase by 50%, 40%, and 30%, respectively (9). This interconnection necessitates solutions that address multiple sustainability goals simultaneously. AV systems are increasingly recognised as a strategy to enhance land-use efficiency, mitigate climate risks, and support rural economies (10–12).

In Türkiye, AV adoption remains limited, with no specific regulatory framework as of 2025. Installations are subject to existing agricultural land protection and unlicensed electricity generation regulations (13,14). Prime agricultural land, irrigated fields, and orchards are generally excluded from development, with preference given to marginal lands (15). In Eskişehir, local spatial plans include provisions for solar energy zones, but compliance with land-use and environmental requirements is essential (16).

Methodology

This research employed a qualitative approach focusing on Eskişehir province. Data were collected in spring 2025 through semi-structured interviews with 14 participants: farmers (n=7), agricultural engineers (n=3), energy sector representatives (n=2), and local public officials (n=2). Interview questions addressed energy–agriculture integration, investment perceptions, climate resilience, and local acceptance.

Data were analysed thematically following Braun and Clarke’s framework, yielding four main themes:

1. Energy independence – 86% of participants stated that AV systems could significantly reduce electricity costs.
2. Water management – Panel shading was expected to reduce evapotranspiration by approximately 25% (17).
3. Agricultural productivity – Yield increases were observed in crops such as tomatoes, peppers, and leafy greens.

4. Implementation barriers – Key obstacles included high capital costs, regulatory uncertainty, and lack of technical training.

Findings and Technical Insights
Literature and field results indicate that appropriate panel height, spacing, and configuration can maintain crop yields while producing electricity (7,18). Shading reduces soil temperature, lowers evapotranspiration, and improves water efficiency (19,20). Early adopters in Türkiye generally favour stilt-mounted systems, though concerns about permitting, financing, and crop selection remain (1,21).

Recommendations for Eskişehir

Configuration: Elevated single- or double-row structures to allow tractor passage and livestock integration (1,20).
Crop pairing: Shade-tolerant crops such as leafy vegetables, alfalfa, legumes, and strawberries; pasture integration to reduce heat stress (20,19).
Water management: Drip irrigation beneath panels and rainwater harvesting channels (19).
Structural design: Consideration of wind loads and snow; ensuring safe access for maintenance (18).
Digital monitoring: Sensors for phenology, soil moisture, and microclimate to optimise shading strategies (7).

Implementation Roadmap

1. Site selection on marginal land; compliance with spatial plans and environmental assessments (15,16).
2. Pilot plots (1–5 ha) to test crop–shading scenarios (1,14).
3. Technical feasibility: panel height ≥3–4 m, transparency 30–50%, row spacing for machinery access.
4. Financing models: self-consumption, cooperative structures, or net-metering; consideration of CAPEX/OPEX impacts (22,14).
5. Policy integration: inclusion in rural development subsidies and agricultural training curricula.

Main Results and Discussion

Technical and Agricultural Insights from the Literature
Dual-use benefits: Appropriate panel height, openness ratio, and row spacing can preserve crop yield while enabling electricity generation (1,2).
Microclimate effects: Shading has the potential to lower soil temperature, reduce evapotranspiration, and improve water-use efficiency (3,4).
Farmer perceptions (Türkiye): Pioneer producers generally exhibit a positive attitude toward AV systems; the most commonly adopted configuration is the "stilt-mounted" system. Key concerns include permitting processes, financing, crop selection, and maintenance (5,6).
Türkiye-focused analyses: Studies from 2024 indicate that certain cities in different climatic zones (e.g., Konya, Kayseri, Manisa) are highly suitable for AV; with proper crop–system matching, AV has broad potential across Türkiye (7).

Design and Crop Recommendations for Eskişehir
Configuration: Elevated single- or double-row structures suitable for tractor–equipment access and integration with cattle grazing/pasture use (5,4).
Row spacing: Should be designed according to the target photosynthetically active radiation (PAR) threshold during midsummer and aligned with tillage and harvest routes (1).
Crop pairings (examples for Eskişehir's climate):

Semi-shade-tolerant crops: leafy vegetables (lettuce/spinach), forage crops (alfalfa), certain legumes, strawberries, etc.
Pasture–livestock integration: reduction of heat stress through shading (4,3).
Water management: Use of drip irrigation beneath panels and rainwater diversion channels to improve water efficiency (3).
Wind/load considerations: Wind loads in Central Anatolia should be factored in; structural anchoring and support systems must prioritise safety and maintenance access (2).
Digital monitoring: Use of sensors for plant phenology, soil moisture, and microclimate to optimise dynamic shading strategies (openness ratio/tracker angle) (1).

Implementation Roadmap for Eskişehir

1. Land and planning compliance: Identification of marginal agricultural land; verification of compliance with zoning plans and environmental requirements (8,9).
2. Pilot plots: Establishment of 1–5 ha pilot sites testing various crop–shading scenarios (5,10).
3. Technical feasibility: Consideration of wind–profitability balance, panel height (≥3–4 m), openness ratio (30–50%), row spacing compatible with agricultural machinery, and single-axis tracking options.
4. Economy/financing: Analysis of CAPEX/OPEX scenarios; adoption of unlicensed self-consumption models, off-YEKDEM direct sales, or balancing of agricultural irrigation loads (11,10).
5. Contractual models: Rental–revenue sharing or net-metering arrangements between farmer, investor, and distribution company; cooperative models (5,10).
6. Monitoring and scaling: Annual evaluation of yield, quality, water use, and biodiversity indicators; scaling up of best practices (4,3).

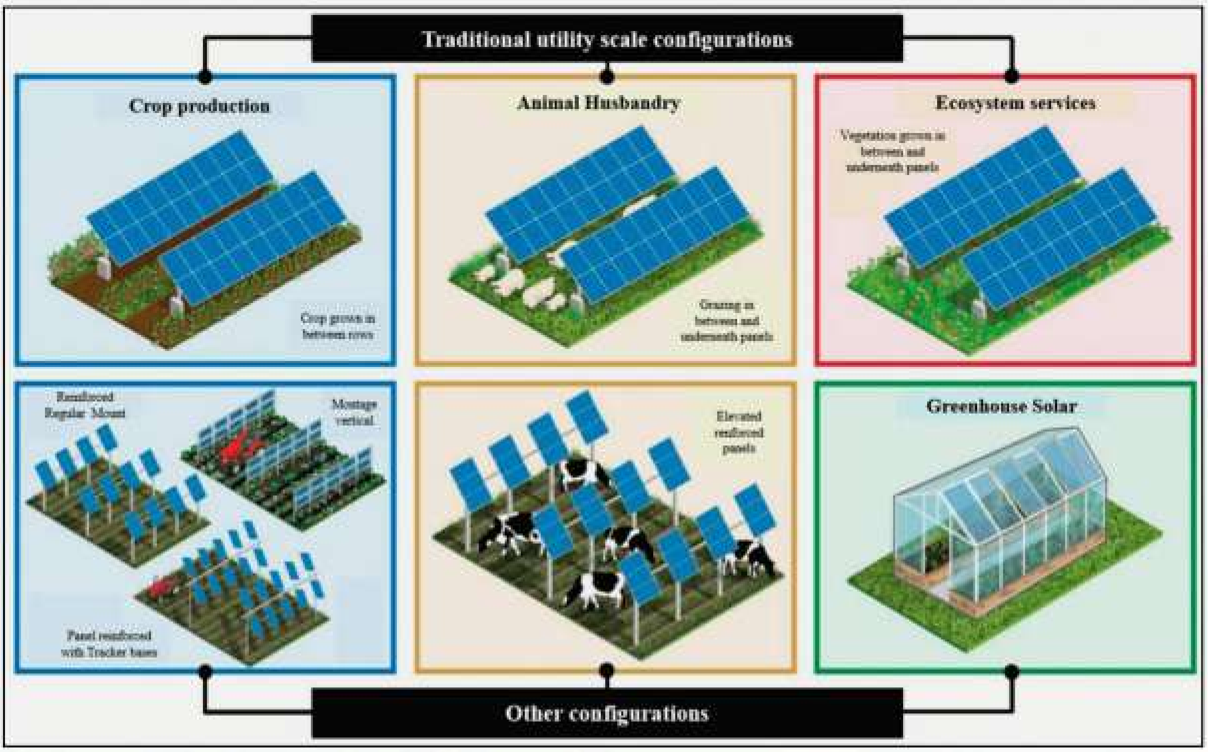


Figure 1. Applications of Solar Energy in Agriculture

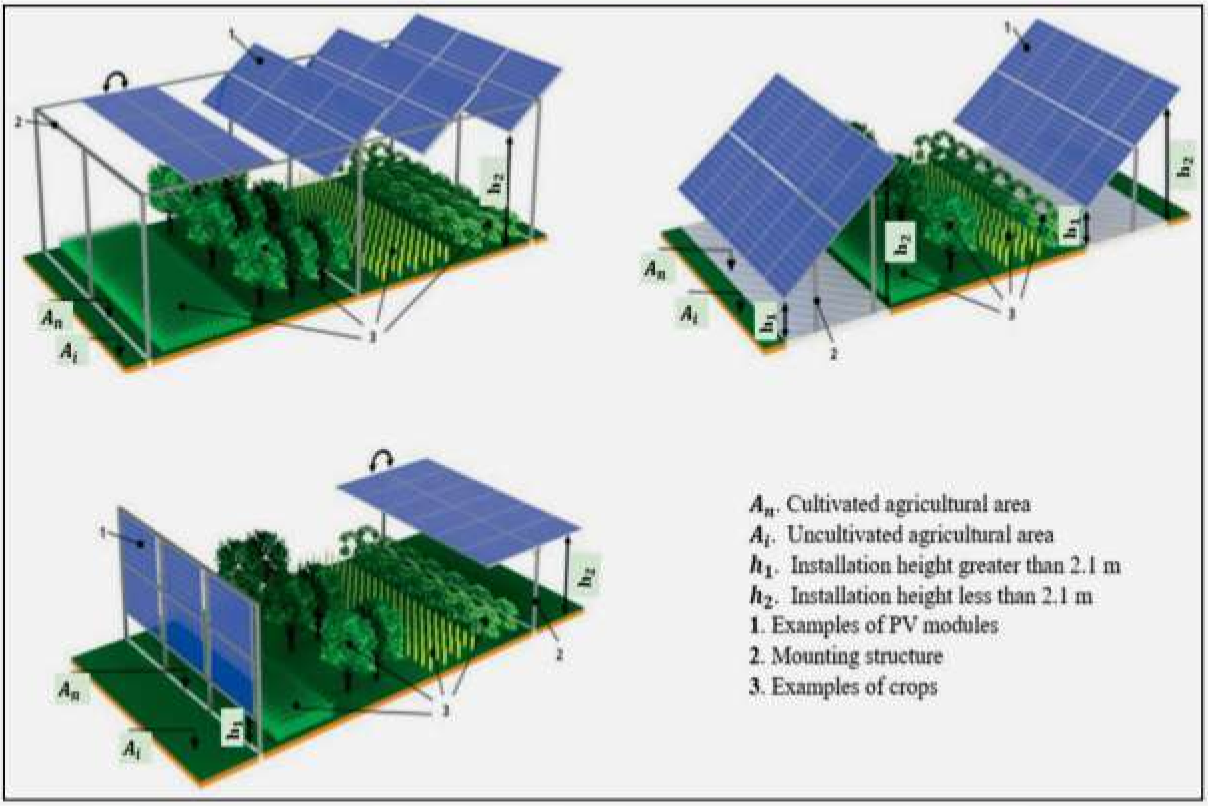


Figure 2. Example of an Agrivoltaic Facility

Conclusion

Limitations and Risks:
Regulatory uncertainty: The absence of agrivoltaics-specific guidelines may prolong permitting processes (1,10).
Land constraints: Prohibition of installations on fertile, irrigated, or perennial croplands increases the burden of proof for “marginal land” designation (8).
Technical risks: Wind loads, snow, and maintenance access require design optimisation (2).
Social acceptance: Farmer expectations, revenue-sharing arrangements, and visual impact management are important considerations (5).

The integration of agrivoltaic systems offers significant opportunities for both the agricultural and energy sectors, as environmental sustainability and aesthetic values must be addressed, particularly in areas where agricultural and energy production are combined. Integrating agrivoltaic systems into landscape design presents an innovative approach that unites these two objectives.

In Eskişehir, agrivoltaic systems can enhance agricultural resilience by improving water-use efficiency and reducing heat stress during the intense solar radiation and increasing drought risks of summer, while enabling dual income generation through concurrent electricity production. For successful scaling, the following are recommended: marginal land selection, elevated designs compatible with agricultural operations, appropriate crop–shading matching, early alignment with local planning and permitting processes, and cooperative/self-consumption-oriented financing (1,10,2).

The widespread adoption of AV systems requires an integrated strategy not only between the energy and agriculture sectors but also involving rural development, education policies, and local government planning. Comparative analyses for the Central Anatolia Region reveal that despite high solar energy potential, there is a significant gap in both knowledge and capital for implementation.

Furthermore, rural development grants from the Ministry of Agriculture and Forestry, as well as KOSGEB support programs, are considered important mechanisms to finance AV investments. This study, linking field analyses conducted in Eskişehir with the environmental and socio-economic characteristics of Central Anatolia, provides a comprehensive framework for how AV systems can be incorporated into Türkiye's rural development policies.

Policy recommendations:

Establish clear legal definitions and permitting procedures for AV investments.
Incorporate AV systems into agricultural education curricula.
Create dedicated incentive models for AV technologies that provide water savings.

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Rejuvenating City Residents with Gerontechnology in Aging Cities

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Abstract
Cities that are growing with their population, volume and problems are also evolving towards becoming aging cities, both in terms of their physical structures and their residents. Just as cities that are constantly being physically renewed in this process are rejuvenated with technological equipment, their elderly residents are also integrating with young technologies for a longer and healthier life with the use of gerontechnological products (technology for elderly use) . The constantly evolving and updated structure of technology ensures that it is the main determinant of the lifestyles of young people. On the other hand, with increasing life expectancy, the elderly also need to integrate with technology, turn to wearable technologies, use health technologies more intensively and especially increase their technological health literacy. As the most recent example, during the Covid 19 pandemic, it was understood how much they needed all kinds of technology use, the importance of monitoring health monitoring programs and other public institutions reaching out to the elderly through these means. All these elements show that the age-friendly city and youth/child-friendly city approaches are integrated in the focus of technology. This study addresses the importance of the technological perspective in the cities of the future for both the physical structure of the city and the elderly city dwellers, and aims to draw attention to the importance of the gerontechnological perspective articulated in smart city-smart building approaches. In the study based on literature review, examples of the increasing use of technology in the elderly policies of city administrations are compiled as social innovative models.

Key Words: Gerontechnology, Smart city, aging, social innovation, wearable technology

Entrance

Aging is a natural and inevitable process that continues from birth to death (1). The basic needs of older individuals include access to healthcare, housing, nutrition, rehabilitation, independence in daily life, self-care, and social communication. The use of digital technologies provides convenience and support for older adults in meeting these basic needs (2). In this process, in addition to physiological and psychological changes, the cumulative effects of social changes such as prolonged exposure to external factors, isolation, and the loss of loved ones also come into play (3).

According to data from the Turkish Statistical Institute (TurkStat), the proportion of the elderly population in the total population was 7% in 2008, 8% in 2013, and 10.2% in 2023 (4). This situation has made it essential to provide a safe home environment and prevent time loss in emergencies, as the care workforce is insufficient to meet the increasing demands for elderly care (5). Digital technologies used to ensure this security are also prioritized in approaches developed for the smart cities in which today's youth will live in the future (6).

In this context, it is clear that services provided to the elderly require up-to-date approaches, along with the simultaneous development of health information technologies (7). Supporting the elderly with technology and increasing their technological literacy is crucial for a shared intergenerational perspective in urban life.

Key Findings

Technologies used to improve the quality of life and meet the care needs of older adults include applications such as home health monitoring devices, emergency buttons, and smart home systems. These technologies help older adults maintain their independence and receive rapid intervention in emergencies. These technologies increase the effectiveness of elder care services and alleviate the burden on caregivers.

Gerontechnology is an approach conceptually derived from the words gerontology and technology, and is the name given to the entirety of aging and technology studies to improve the daily activities of the elderly (8). Studies in the field of gerontechnology are organized within the framework of five basic support areas for the elderly to live a healthier and more active life. This framework is called the Five Methods of Gerontechnology and consists of the following categories: prevention, development, compensation, care support and research (9).

Despite the positive attitudes towards the use of technology among the elderly in Turkey, it has been found that only 8.3% of the elderly population recognizes the term gerontechnology (10). Studies have examined the use of digital health services by elderly individuals and have stated that they should be supported in terms of access to these services, information and education (11). The importance of digital technologies used in health services is increasing and studies have revealed how these technologies facilitate the access of elderly individuals to health services (12,13).

In Turkey, the Ministry of Health launched the e-health project in 2003 as part of the Health Transformation Project, aiming to establish a health information system encompassing all aspects of healthcare. This project aims to consolidate health data nationwide, provide citizens with access to their own health information, and create a database containing lifelong health records (14).

The ability of today's elderly to speak the same technological language as younger people and to monitor their health status in digital environments depends on their digital literacy. The skills individuals develop to adapt to constantly changing and advancing information technologies are defined as "digital literacy." Digital literacy encompasses not only technical knowledge but also cognitive, social, and cultural skills, enabling individuals to integrate into today's world (15).

An examination of the healthcare systems of developed countries reveals the widespread use of technological applications such as e-Health, telemedicine, mobile health, digital hospitals, wearable technology, and robotic surgery. These technological advancements are changing the delivery and accessibility of healthcare services (16, 17). Undoubtedly, this process is related to policies regarding the vocational training of young people as well as new space-use decisions. For example, developed countries are shifting their healthcare investments toward e-Health systems and related technologies rather than large hospital construction. This not only differentiates healthcare institution construction policies but also expands the scope of healthcare services, making them more accessible through telemedicine and mobile applications. Therefore, similar developments in urban space-use decisions are inevitable in educational settings.

The principle of working with robot colleagues will also be important in young people's future career decisions. Japan, a pioneer in healthcare technology, has robot nurses and toilet robots equipped with artificial intelligence. These robot nurses play an active role in blood sample collection, education, and nursing services; they can perform urine tests in 20 seconds and print or email the results to a doctor (18). This will change time and space requirements such as collecting materials, delivering them to laboratories, and setting time limits for storing test results. This service, which is used more frequently by the elderly population, will become a more significant factor in the future of young people's healthcare.

The use of technology in healthcare has come to the forefront in almost all its dimensions during the Covid-19 period. There has been a great explosion in both institutional and personal digital application use (19, 20, 21). Telemedicine robots providing remote care to Covid-19 patients have been used in hospitals in Boston. The US "Cody" robot assists in bed bathing, dressing, and rehabilitation of stroke patients. In Belgium, "Pepper" robots greet and guide visitors in hospitals (22). Again, the awareness and expectation that other epidemics will spread in the future of the world also show that technological regulations in this regard will maintain their importance.

Conclusion

In conclusion, while the use of digital technologies of the future, with the dimensions mentioned above, in all areas such as urban planning, settlement, transportation, etc., opens new perspectives for young people, a visionary perspective is also required for the healthier aging—and, in a sense, rejuvenation—of the aging population. The proficiency of older individuals in using new technologies should be increased not only for their physical health but also for their mental well-being. The trend toward digitalization and robotization in healthcare delivery and health data monitoring should be evaluated from a technical, ethical, and legal perspective in all areas of management policies.
In many parts of the world, critical health information such as heart rhythm and body temperature of individuals can be monitored by health centers with the help of devices used through wearable technologies (e.g. watches, rings, shoes, glasses, phones, etc.). These technological developments allow for continuous and more effective health monitoring. This trend should be supported, and "monitoring and surveillance" policies should be planned sensitively on the axis of freedom/security. All these processes will affect urban health policies and space usage decisions. Especially the elderly care sector and local social service policies to be implemented should be shaped accordingly.

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Developing Green Human Capital through the Model United Nations:

A Social Innovation Perspective

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ABSTRACT

This paper explores how Model United Nations (MUN) programs can contribute significantly to the development of green human capital among youth. Drawing on the theoretical frameworks of Green Human Resource Management (Green HRM) and social innovation, the study investigates the ways in which MUN fosters essential environmental values, skills, and civic engagement. Using a qualitative case study methodology focused on a group of high school students who participated in an international MUN conference in Doha, Qatar, the paper analyzes multiple sources of data including teacher observations and student reflections. Findings suggest that MUN acts as an informal but powerful tool for promoting green HRM principles by encouraging value-based participation, raising environmental awareness, and enhancing students' understanding of global sustainability policies. The study concludes with practical recommendations for educators and policymakers to integrate MUN and similar programs into educational curricula, thus supporting the wider agenda of sustainable development and green human capital formation.

Key words: Green Human Capital, Model United Nations, Social Innovation, Sustainable Development, Environmental Education.

Introduction

The 21st century has brought forward pressing global environmental challenges that call for a transformation in how future generations are educated and empowered. Climate change, biodiversity loss, and resource depletion have made it clear that sustainable development must be a key priority worldwide. One important aspect of this transformation is the development of green human capital — the knowledge, skills, values, and behaviors that support sustainable practices and environmental stewardship.

Green human capital is increasingly recognized as essential for organizations and societies aiming to meet environmental goals and transition to a low-carbon economy. However, formal education systems, especially at the secondary and higher education levels, often lack comprehensive curricula focused on environmental education and sustainability competencies. In many countries, there is a gap in the practical training of young people to become environmentally responsible citizens and future professionals.

In this context, informal and non-traditional learning experiences play a vital role. Model United Nations (MUN) is an educational simulation where students role-play delegates to the United Nations and engage in debates on global issues. Traditionally, MUN enhances diplomatic, negotiation, and communication skills. However, its potential to contribute to environmental education and the development of green human capital has received less attention.

This paper investigates how participation in MUN programs can foster green human capital among youth, using a social innovation perspective. It argues that MUN's interactive and participatory format creates opportunities for young people to acquire environmental knowledge, develop pro-environmental values, and build civic engagement skills necessary for sustainable development.

Literature Review

Green human capital has gained increasing attention as a critical element in sustainable development. It encompasses not only knowledge and skills related to environmental issues but also attitudes and values that drive sustainable behavior (Renwick et al., 2013). The role of education—both formal and informal—is crucial in nurturing this capital. However, many traditional education systems fall short of integrating environmental competencies effectively (Albareda & Lozano, 2007).

Previous research highlights the value of experiential and simulation-based learning as effective tools in developing sustainability competencies (Jabbour, 2011). Model United Nations, as a form of experiential learning, has demonstrated benefits in diplomacy and leadership development, but limited studies explicitly address its impact on green human capital formation. This research seeks to fill this gap by linking MUN participation with green HRM and social innovation frameworks.

Theoretical Framework

The study is grounded in two interrelated theories: Green Human Resource Management (Green HRM) and social innovation. Green HRM focuses on the development and management of human resources to achieve environmental objectives, emphasizing value-based leadership and employee engagement in sustainability (Renwick et al., 2013). Informal educational settings like MUN align well with Green HRM by promoting voluntary, value-driven participation.

Social innovation theory views new social practices as mechanisms for addressing complex societal problems (Moulaert et al., 2005). MUN, by simulating global governance processes, serves as a platform for social innovation in education, fostering creative solutions and civic responsibility toward sustainability.

Methodology

This study employs a qualitative case study approach focused on a group of high school students from Al-Maarefa International School in Jeddah who participated in the MUN conference held in Doha, Qatar, in 2013. The choice of this case allows for an in-depth exploration of the educational and social impacts of MUN on youth environmental awareness and capabilities.

Data collection involved multiple methods to ensure triangulation and rich insights. Teacher observation logs documented students' participation and behavioral changes during the conference preparation and actual event. Student written reflections provided personal accounts of learning experiences and shifts in perceptions related to environmental issues. Additionally, semi-structured debriefing interviews with a sample of students enabled further elaboration on how MUN influenced their attitudes and skills.

The data was thematically analyzed to identify key patterns relating to environmental knowledge, value development, and civic engagement. The analytical framework was guided by concepts from Green Human Resource Management (Green HRM), which emphasizes the role of informal learning and value-based participation in building sustainable human capital, and social innovation theory, which views novel social practices as drivers of systemic change.

Main Results and Discussion

The analysis revealed three significant dimensions through which MUN contributed to the development of green human capital:

1. Environmental Awareness and Knowledge
   Students demonstrated a heightened understanding of global environmental issues such as climate policy, renewable energy alternatives, and international cooperation mechanisms. The research component required for preparing

position papers on environmental topics prompted in-depth learning. Several students noted that the complexity and urgency of environmental challenges became more tangible through role-playing as affected nations. MUN also encouraged critical analysis of international agreements such as the Paris Climate Accord and the role of the United Nations Environment Programme.

2. Value Orientation and Ethical Reasoning
Participation in MUN fostered strong environmental ethics and empathy, particularly for students assigned to represent countries severely impacted by climate change and environmental degradation. The immersive experience nurtured a sense of responsibility and moral commitment to sustainability, echoing key principles of Green HRM which emphasize value-driven leadership. Students reported a deeper awareness of ethical dilemmas in climate policy and began considering the balance between economic development and environmental conservation.

3. Skills Development and Agency for Action
The simulation strengthened critical skills including negotiation, public speaking, diplomacy, and leadership, all framed within sustainability discourse. Notably, many students expressed increased confidence and motivation to engage in environmental advocacy beyond the classroom, including joining clubs, volunteering, and pursuing green career pathways. These actions reflect the transfer of learning into practical initiatives and personal transformation.

Furthermore, the collaborative nature of MUN facilitated peer-to-peer learning, where students inspired and mentored one another in researching environmental topics, preparing speeches, and formulating solutions. This horizontal exchange of knowledge and motivation not only strengthened individual capacities but also fostered a shared sense of purpose and community engagement. Such dynamics align with social innovation theory, which emphasizes grassroots empowerment and the co-creation of new practices that challenge traditional educational hierarchies.

Limitations and Challenges

While the study provides valuable insights, several limitations should be acknowledged. The small sample size and focus on a single case limit the generalizability of findings. Additionally, reliance on qualitative data may introduce subjectivity, although triangulation helped mitigate this risk. Future research could expand the sample and incorporate quantitative measures to assess long-term impacts on green behavior.

Future Research Directions

Building on the findings, future studies should investigate the longitudinal effects of MUN participation on green human capital development. Tracking students' career paths and environmental engagement post-MUN could provide deeper understanding of sustained impacts. Moreover, exploring ways to formally integrate MUN with environmental curricula would be a valuable contribution to education policy.

Conclusion

This study provides strong evidence that Model United Nations programs can serve as effective informal learning environments for developing green human capital. By integrating environmental topics into diplomatic simulations and fostering collaborative problem-solving, MUN not only enhances knowledge but also inspires proactive civic behavior oriented towards sustainability.

The paper recommends that educational institutions and policymakers recognize and expand the role of MUN and similar initiatives in youth education frameworks. Specifically, integrating explicit environmental dimensions in MUN agendas and supporting reflective practices can maximize their impact on sustainability competencies.

In conclusion, as the world faces mounting environmental crises, cultivating green human capital through innovative social learning models like MUN is both timely and essential. These programs can nurture a generation equipped with the knowledge, values, and skills needed for a sustainable future.

Future research could investigate the long-term impact of MUN participation on students' career paths, environmental activism, and civic engagement, particularly in underrepresented or resource-limited contexts. Comparative studies across different cultural and institutional settings may also provide further insight into the scalability and adaptability of MUN as a green human capital development tool.

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From Collective Trauma to Community Resilience: A Proposed Community-Based Social Work Model for Post-Disaster Psychosocial Intervention in Türkiye

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ABSTRACT

Disasters cause not only physical destruction but also long-term psychosocial consequences, particularly in contexts with repeated exposure to large-scale crises. In Türkiye, the recent earthquakes have revealed critical gaps in post-disaster psychosocial interventions, highlighting the need for sustainable, community-based social work models. This study proposes a trauma-informed, community-based psychosocial intervention model designed to foster community resilience in the aftermath of disasters. Grounded in the trauma-informed approach developed by Harris and Fallot (2001), the model integrates principles of safety, trust, collaboration, empowerment, and cultural sensitivity. It emphasizes active participation of affected communities, strengthening local support networks, and ensuring that interventions are responsive to collective trauma dynamics. The proposed model aims to bridge the gap between immediate crisis response and long-term recovery by embedding psychosocial services into existing community structures. In doing so, it addresses both the visible and invisible impacts of disasters, from grief and displacement to social fragmentation. The paper outlines the theoretical framework, operational components, and expected outcomes of the model, offering a practical and adaptable tool for social work professionals and policymakers. Ultimately, the model seeks to transform post-disaster intervention from a reactive, short-term service into a proactive, resilience-oriented process that empowers communities to recover, rebuild, and thrive.

Key words: Disaster Preparedness, Psychosocial Support, Collective Trauma, Community Resilience, Trauma-Informed Approach, Social Work

Introduction

Disasters, whether natural or human-made, often leave behind consequences that extend far beyond physical destruction, leading to deep-seated psychosocial impacts on individuals and communities [1]. In Türkiye, where the frequency and severity of disasters such as earthquakes, floods, and industrial accidents remain high, the aftermath often manifests as collective trauma—a shared psychological wound that affects not only individuals directly exposed to the event but also the wider community [2].
This form of trauma, characterized by disrupted social cohesion, diminished trust, and prolon-

ged psychological distress, necessitates comprehensive interventions that address both individual and community-level needs [3]. This framework recognizes the pervasive impact of trauma and integrates this awareness into all aspects of service delivery, with the goals of preventing re-traumatization, fostering safety, and promoting empowerment [4]. While widely adopted in various mental health and social service settings worldwide, the adaptation of trauma-informed practice to large-scale disaster contexts, particularly in Türkiye, remains limited [5,6]. A community-based social work model informed by trauma principles offers a promising pathway for bridging this gap [7]. Such a model prioritizes local participation, cultural sensitivity, and the mobilization of community strengths, enabling affected populations not only to recover but to build resilience against future adversities [8,9]. By aligning with the principles of collective empowerment, this approach situates psychosocial intervention within the broader framework of social justice and human rights [10]. The present study proposes a comprehensive, community-based social work model for post-disaster psychosocial intervention in Türkiye, grounded in trauma-informed principles and ecological systems thinking [4,8].
The aim is to provide a structured, adaptable, and culturally relevant framework that addresses the complex and layered effects of collective trauma, while enhancing community resilience as a cornerstone of sustainable recovery [9,11].

Methodology

This study adopts a qualitative research design to develop a community-based social work model for post-disaster psychosocial intervention in Türkiye. The model is grounded in the principles of trauma-informed practice **[4]** and ecological systems theory **[12]**, integrating both frameworks to address the multi-layered needs of disaster-affected populations [8].

The trauma-informed approach, originally conceptualized by Harris and Fallot (2001), emphasizes safety, trustworthiness, peer support, collaboration, empowerment, and cultural, historical, and gender sensitivity **[4]**. This study adapts these principles to disaster contexts, aiming to prevent re-traumatization while fostering resilience and empowerment in affected communities [5,13].

Ecological systems theory provides a lens for understanding the dynamic interplay between individuals and their environments across multiple layers; microsystem, mesosystem, exosystem, macrosystem, and chronosystem **[12]**. In the context of disaster response, this perspective highlights the necessity of interventions that operate not only at the individual level but also across family, community, institutional, and policy domains **[8,14]**.

Data for this study were gathered through an integrative literature review of national and international studies on post-disaster social work interventions, trauma-informed care, and community resilience **[3,5,8]**. Priority was given to studies addressing the unique cultural, social, and political dynamics of Türkiye, particularly those emerging from the aftermath of the 2023 Kahramanmaraş earthquakes **[9,11]**.

The proposed model synthesizes insights from these sources to create an adaptable, culturally relevant framework that emphasizes local participation, empowerment, and sustainable capacity building [8,13]. The methodology ensures that the model is both evidence-based and contextually appropriate, reflecting the lived experiences of disaster-affected communities in Türkiye **[5,9]**.

Main Results and Discussion

The findings from the literature review and contextual analysis highlight significant structural and operational gaps in Türkiye's post-disaster psychosocial support framework [9,11]. While psychosocial intervention is formally recognized as a core component of national disaster management strategies [15], its operationalization remains inconsistent and fragmented [16]. Most interventions are implemented in the acute phase, often ending within weeks or months, without sufficient follow-up mechanisms to address long-term mental health needs or to strengthen community resilience [4,8,13]. The lack of standardized protocols, insufficient coordination among agencies, and uneven regional coverage further exacerbate these shortcomings, particularly in rural and socioeconomically disadvantaged areas [14,17].

Integrating trauma-informed practice into disaster-specific social work frameworks offers a promising avenue for addressing these gaps [4,5,18]. The trauma-informed approach emphasizes principles such as safety, trust, empowerment, and cultural sensitivity, which, when adapted to disaster contexts, can reduce the risk of re-traumatization and foster community recovery [8,19]. For example, training local volunteers and community leaders in trauma-informed communication can enhance the capacity of affected communities to provide peer support, while also bridging the gap between professional interventions and local coping mechanisms [13,20].

When combined with ecological systems theory, the model expands its scope to address needs at multiple levels: individual (psychological support, counseling), family (strengthening intra-family communication and support systems), community (group-based resilience programs, mutual aid networks), institutional (capacity building for local organizations), and policy (advocating for disaster-inclusive social policy reforms) [8,12,14]. This multi-layered perspective is crucial in contexts like Türkiye, where social, cultural, and institutional factors intersect to shape recovery processes [11,17].

The aftermath of the 2023 Kahramanmaraş earthquakes provided a stark illustration of the need for such an integrated model [9,11]. Field observations and reports documented that while emergency relief reached urban centers relatively quickly, rural and hard-to-access areas experienced delays in receiving psychosocial support [14,16]. Moreover, interventions in many locations lacked cultural tailoring, resulting in reduced engagement and lower sustainability of programs [19].

Comparative analysis with international cases demonstrates that community-based, trauma-informed interventions—when embedded within existing local structures—consistently produce better long-term outcomes in mental health, social cohesion, and disaster preparedness [12,20,21]. In countries such as Japan and New Zealand, integrating psychosocial support into community disaster drills and preparedness programs has strengthened both individual coping capacities and collective resilience [21,22]. Adapting such practices to Türkiye's socio-cultural landscape, while leveraging existing social capital, can enhance both effectiveness and sustainability [8,11].

Finally, the proposed model includes a robust monitoring and evaluation framework to track psychosocial recovery indicators over time [15,18]. This framework will assess variables such as PTSD prevalence, community participation rates, and self-reported resilience, enabling continuous refinement of interventions [12,19]. By institutionalizing these practices, the model aims not only to respond to immediate post-disaster needs but also to embed a culture of preparedness, mutual support, and psychological well-being into the fabric of communities across Türkiye [8,11,14].

Conclusion

This study proposes a community-based, trauma-informed social work model for post-disaster psychosocial intervention in Türkiye, aiming to address the structural, operational, and cultural gaps identified in the current disaster response framework [4,8,9]. The findings emphasize that recovery-oriented disaster management must extend beyond short-term relief efforts to incorporate long-term resilience-building strategies that address the psychological, social, and structural dimensions of disaster impact [8,12,14].

First, there is a pressing need for continuous professional development of disaster field personnel. Social workers and allied professionals should receive periodic, updated training that integrates trauma-informed principles, cultural competence, and context-specific disaster response skills [5,13,19].

Second, the adoption of a risk reduction-oriented approach is essential, ensuring that interventions address preparedness and prevention as much as response and recovery [8,14,21].

Third, the role of social workers must be explicitly defined in disaster legislation and national contingency plans, specifying their authority, responsibilities, and integration points with other services [9,11,15].

Fourth, trauma-informed practice should be established as a professional requirement for all personnel operating in post-disaster contexts, to minimize re-traumatization and enhance the efficacy of psychosocial interventions [4,5,18].
Fifth, community education programs should be systematically designed and implemented to improve public awareness, coping strategies, and mutual aid capacity before, during, and after disasters [12,13,20].
Sixth, risk analysis and vulnerability mapping must be institutionalized as foundational tools for disaster planning, enabling targeted allocation of resources and prioritizing populations with heightened vulnerability, such as the elderly, persons with disabilities, and socioeconomically marginalized groups [8,14,17].
Seventh, interdisciplinary collaboration should be strengthened, ensuring that social workers coordinate with psychologists, medical staff, urban planners, local administrations, and NGOs to deliver integrated, comprehensive disaster services [12,20,22].
Eighth, systematic data collection from the field should inform evidence-based policy development, ensuring that each disaster experience translates into improved preparedness and resilience in future events [14,18,21].
Finally, bridging the policy–implementation gap is crucial. Disaster-related policies must not remain at the legislative or strategic planning stage; they should be translated into concrete programs, supported with adequate funding, and monitored for effectiveness [8,15,21]. Closing this gap will ensure that resilience-building measures yield tangible and sustainable outcomes for affected communities [12,14,20].
By operationalizing these recommendations, Türkiye can transition from a reactive, short-term relief paradigm toward a proactive, resilience-oriented disaster management system that safeguards both individual well-being and community cohesion [8,12,14].

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Resilient Futures: Youth Leadership and Smart Innovation in Strășeni's Urban Transformation

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ABSTRACT

Strășeni (pop. ≈21,500) is a Moldovan city pursuing inclusive development and digital literacy programs .I explore how youth leadership combined with smart-innovation can advance Strășeni's urban resilience. Using a qualitative case study (document review, interviews with 25 local stakeholders, and youth–official workshops), we identify synergies between youth engagement and smart-city strategies. We find that the city has launched relevant initiatives – for example, a participatory anti-corruption "integrity island" plan in 2017 and EU-backed mobility projects – yet lacks formal channels for sustained youth input. Young people we interviewed proposed practical tech-based ideas (e.g. a co-designed bus-tracking app and bike-share system) to address transit and service gaps. Participants noted that digitally savvy youth can serve as "smart ambassadors", bringing innovation and accountability when involved in planning.

Keywords: Strășeni; youth participation; smart city; urban resilience; innovation

Introduction

Strășeni, a mid-sized municipality in central Moldova, serves as a local administrative and industrial hub (≈21,500 residents). Like many post-Soviet towns, it faces infrastructure deficits (aging transit, limited public services) and a "youth bulge" (roughly 20–25% of residents are under 30). Strengthening resilience – the capacity to adapt to economic, social, and environmental stresses – is a national priority (e.g., under EU4Moldova and UNDP programs). Central to this is community engagement, especially of youth: in fact, Moldova's 2023 amendments to the Law on Youth explicitly aim to support youth-led social innovation. Programs like "Cities4Youth" similarly emphasize that urban sustainability depends on raising youth awareness and ensuring their "active participation" in city-building. Nationally, Moldova has pursued smart-city initiatives in larger cities (e.g. smart water and lighting systems in Cahul/Ungheni), but integration of tech and youth voices in smaller towns remains limited. Local leaders recognize this gap: Leonid Boaghi, Mayor of nearby Sireți and President of Moldova's Young Mayors Platform, stresses that strengthening networks of young elected officials yields "participatory, inclusive, and effective" governance. In this context, our study asks: How can youth leadership and smart innovation together transform Strășeni into a more resilient city? We focus on Strășeni's specific challenges and opportunities, aiming to derive lessons for similar small cities.

Methodology

I conducted a qualitative case study of Strășeni, triangulating (1) documentary analysis, (2) stakeholder interviews, and (3) co-creation workshops. First, I reviewed municipal plans and reports (including the 2017 integrity/anti-corruption plan) and EU/UN project documents on Strășeni (e.g., REALLOCATE mobility assessments). Second, I interviewed 25 participants in 2024: ten municipal officials (e.g. vice-mayor, school directors), ten local youths (age 16–27), and five NGO/civic leaders. These semi-structured interviews probed perceptions of smart-city concepts, barriers to youth engagement, and priority projects. Third, I held two participatory workshops with mixed groups of 5–6 youth and 5–6 officials. In these sessions, participants mapped local assets and challenges, and co-developed ideas (e.g. identifying safe bike routes, sketching mobile service prototypes). I coded interview and workshop data for themes relating to youth roles, innovation opportunities, and governance processes. This mixed-methods approach allowed us to contrast official plans with community insights and to identify where youth-driven innovations might align with resilience goals.

Main Results and Discussion

Existing Initiatives

Strășeni's leaders have shown openness to public input. Notably, the 2017 strategic development plan (an "integrity island" anti-corruption initiative) was created "in a participatory manner" involving city managers, NGOs and citizens. More recently, the municipal school hosted a digital literacy workshop (Apr 2024) where ~80 students learned to use online government services (e-diplomas, e-ID, etc.). These actions build youth capacity and trust. However, we found no permanent youth body (like a youth council) to channel young people's ideas. As one official observed, Strășeni has had volunteer youth initiatives, "but there's no permanent youth platform now." In practice, many youth suggested more engagement: for instance, some students reported interest in regular hackathons or tech clubs to solve city issues.

Mobility and Infrastructure

Transportation emerged as a pressing challenge. Strășeni currently relies on *one* public bus line (run by a private operator), whose service is often criticized for delays and inaccessibility. The city also lacks organized parking or EV charging, and has virtually no bike lanes or pedestrian infrastructure. Youth workshop participants highlighted traffic congestion during school hours and unsafe crossings near campus. They proposed tangible smart solutions: a smartphone app for real-time bus schedules and fares (a prototype "Strășeni Go" app); dedicated e-bike stations; and solar-powered, IoT-enabled benches and lighting at transit stops. These ideas align with broader smart-mobility trends: for example, installing GPS trackers on buses to optimize routes, and using digital signage to alert citizens of schedules or delays. Importantly, officials reacted positively. After hearing the youth proposals, the Mayor remarked that the ideas were practical and "we should explore funding for at least the app." This indicates that youth-generated solutions can be technically sound and low-cost once institutional support is offered.

Digital Innovation and Services

Moldova's national push for e-government creates openings for youth-led innovation. Strășeni's schools now have computer labs and internet, thanks to E-Governance Agency efforts. With this base, several youths suggested organizing civic-hackathons: e.g. student teams could design a local web portal or data dashboard (perhaps displaying air quality, bus times, or events). One NGO interviewee noted that youth know older residents who struggle with paperwork; co-creating a "Municipal Guide" app where students help elders submit forms was proposed as a digital inclusion project. Our analysis echoes findings that empowering young people with tech skills can help bridge rural-urban divides. Rather than setting up many physical kiosks, Strășeni could enable online service use if youths mentor their communities. This participatory, digital co-design aligns with models in the literature: globally, integrating tech-savvy youth can leapfrog infrastructure gaps in smaller cities and villages.

Youth Engagement

When included, youth contribute creativity and accountability. In our workshops, young participants showed enthusiasm: they drafted a "Strășeni Smart Map" integrating bus lines, free Wi-Fi spots, and green spaces, and insisted on English labels to connect internationally. Both youth and officials urged the formation of a Youth Advisory Council (a recommendation I echo). This formal body would meet quarterly to advise on development plans. Such councils exist elsewhere – for example, Brisbane established a Youth Advisory Council to capture young people's visions for the city. Evidence from Brisbane's "Plan Your Brisbane" project is instructive: an online gamified workshop engaged ~18,000 young people and produced thousands of ideas on housing, transport and green space. Crucially, that initiative also set up an official Youth Council so ideas led to policy. In Strășeni, a similar framework could ensure youth ideas don't fade after pilot events.

Stakeholder Insights

Interviewees repeatedly noted that youth involvement must be championed by leaders. Mayor Casian of Strășeni observed in 2018 that citizens' involvement "depends first and foremost on the ability of the mayor to persuade them… to get involved" – a lesson applicable to youth as well. During a 2016 Chișinău Smart City Hackathon, Moldova's IT Deputy Minister Tarlev likewise urged tapping young talent: "changes… can come, first of all, from those… who are familiar with new technologies… and have a creative mindset". These perspectives underscore the need for officials to actively engage young innovators.

Challenges

Several obstacles exist. First, funding is limited: Strășeni's municipal budget is modest and cannot alone cover many high-tech projects. Yet interviewees noted opportunities to seek external grants (EU4Moldova, UNDP, etc.) and private partnerships. For instance, Moldova's EU4Moldova Key Regions program (focused on other districts) provides a model for pooled resources on mobility and inclusiveness. Second, mindsets can slow change: some older officials initially doubted youth capacity. This stigma is eroding, however; after witnessing confident student presentations, the school principal now invites local IT volunteers for talks. Finally, digital connectivity is patchy: while central Strășeni has reliable mobile internet, some outskirts do not. Bridging this may require national telecom policy.

Synthesis

My findings suggest a strategic roadmap for Strășeni. First, **institutionalize youth voice**: create a municipal Youth Advisory Council and hold annual "Smart Strășeni" forums. Second, **enhance digital education/infrastructure**: integrate ICT and civic-tech training into school curricula (continuing efforts like the E-Governance Agency's program). Third, **pilot co-created smart projects**: for example, a "Smart Mobility" scheme where a student team works with engineers to outfit buses with GPS trackers and publish real-time schedules, while the city renovates a bus stop with solar lighting and QR-code feedback. These steps – small-scale but co-designed – would generate visible results and reinforce trust in participation. In summary, when youth lead innovation, they tend to produce context-appropriate, cost-effective solutions. Over time, this builds a feedback loop: empowered youth feel valued, stay engaged, and help the city adapt to challenges (economic shifts, climate impacts, etc.).

Conclusion

Strășeni's resilient future hinges on integrating empowered youth leadership with smart-city innovation. My case study shows that informed, motivated young people can enrich governance and spearhead sustainable solutions if given clear channels. To realize this, I recommend that Strășeni's authorities:

- **Institutionalize youth participation:** Form a standing Youth Advisory Council to review plans and budgets.
- **Expand digital education:** Make ICT and e-government literacy core to school programs, building on existing government workshops.
- **Co-develop pilot projects:** Partner with youth to launch tech-driven pilots (e.g. smart transit apps, solar infrastructure).

These combined actions align with Moldova's broader aim of inclusive growth and with successful examples worldwide. Implementing them would create technology-driven public services that reflect young people's needs and creativity, thus fortifying Strășeni's urban resilience. Finally, we note that even small cities can teach larger lessons: by engaging its next generation in innovation, Strășeni may become a blueprint for other towns seeking sustainable, youth-led development. Future research should monitor outcomes (such as app usage rates or youth satisfaction surveys) to refine this model. Ultimately, as experts underscore, the battle for sustainable development is "won or lost in cities, and it will be young men and women who will be leading the charge".

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Multiscalar Planning in Urban Energy Transformation: Renewable Energy Usage and Environmental Impact Management in Turkey

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ABSTRACT

This article examines the environmental impacts of renewable energy use in cities and focuses on how these impacts can be managed through spatial planning. The analysis, developed through Turkey's energy policies and planning practices, examines the Karapınar SPP and İzmir WPP examples in detail and explores solutions through approaches such as environmental justice, cumulative impact assessment, and multi-scale planning strategies. Additionally, innovative practices from countries like Germany, China, Denmark, and the Netherlands are compared and evaluated. In conclusion, cities' energy transitions should aim not only at production but also at environmental sustainability, social participation, and spatial integration.

The study examines the environmental impacts of renewable energy investments in cities and investigates how these impacts can be managed through spatial planning strategies. In the Turkish context, the Karapınar Solar Power Plant (GES) and İzmir Wind Power Plant (RES) projects are analyzed as case studies for comparative analysis. Using a case study method supported by document analysis, spatial plans, and environmental reports, the study observed key issues such as habitat loss, visual landscape transformation, land use conflicts, and limited community participation. The results indicate the need for cumulative impact assessment, multi-scale planning consistency, and environmental justice principles to make energy transition in cities more sustainable and socially acceptable.

Additionally, international practices in Germany, China, Denmark, and the Netherlands were evaluated through comparative policy analysis. These examples demonstrate innovative planning models such as energy cooperatives, participatory design processes, landscape-sensitive site selection, and integrated ecological frameworks. However, Turkey's planning system remains highly centralized and lacks participatory decision-making and cumulative assessment mechanisms.

The study concludes that urban energy transformation should not focus solely on production capacity but must also incorporate environmental sustainability, social equity, and spatial integration. Strategic planning tools that link energy policies with land use, ecological protection, and public participation will contribute to the development of resilient, equitable, and future-oriented urban energy systems.

Keywords: Renewable Energy, Urban Planning, Environmental Impact, Energy Transition, Environmental Justice, Participatory Planning

Introduction

Renewable energy refers to energy types obtained from sources such as solar, wind, geothermal, hydroelectric, and biomass, which are constantly renewed in nature and pose no risk of depletion. These sources offer cleaner, safer, and more sustainable solutions to climate change and environmental degradation caused by fossil fuels; they are directly aligned with sustainable development goals. In Turkey, these energy types are considered a strategic priority to enhance energy supply security and reduce external dependency. However, energy production, particularly in fossil fuel-based systems, is one of the main causes of environmental degradation; these systems account for 72% of global carbon emissions, contributing to air, water, and soil pollution and threatening biodiversity (IEA, 2022). In 2023, the energy sector produced 15.1 gigatons of CO_2 equivalent emissions, reaching the highest level to date (UNEP, 2024). In this context, the widespread adoption of renewable energy systems at the urban scale has become a necessity.

The environmental benefits of renewable energy include reducing carbon emissions, conserving natural resources, and supporting biodiversity through appropriate planning. However, limitations such as land use, habitat fragmentation, negative impacts on bird migration routes, and the degradation of hydroecosystems must also be considered. In this context, the concept of "clean energy" encompasses production technologies with low carbon emissions and minimal environmental impact (such as solar energy, wind energy, hydrogen, and low-emission nuclear energy).

An integrated approach to energy production and environmental management is also directly related to urban landscape planning. Urban landscapes should be redefined as multifunctional areas that combine energy and ecological functions. Public green spaces such as parks, playgrounds, squares, and greenways enhance social interaction and improve urban quality of life. On the other hand, ecological landscapes contribute to carbon sequestration by preserving natural balance through natural areas that provide habitats, afforestation areas, and ecological corridors. Blue and green infrastructure, which includes components such as rain gardens, ponds, permeable surfaces, and carbon forests, improves water management while also playing an effective role in combating climate change. On the other hand, productive landscapes such as urban agriculture areas, renewable energy production sites, and environmental research centers support economic production while also contributing to environmental sustainability.

In conclusion, urban landscapes play a crucial role in shaping the quality of life in cities. Work and production landscapes support economic production through urban agriculture areas, renewable energy production facilities, and environmental research centers, thereby strengthening the self-sufficiency of urban systems. Transition landscapes function as art, event, and rehabilitation areas aimed at soil improvement, social transformation, and community participation, thereby contributing to the achievement of environmental justice.

A holistic planning approach that considers all these components plays a fundamental role in building resilient cities that support energy transition and integrate environmental, social, and economic sustainability.

Turkey's Energy Transition By Year

Turkey's energy policies and practices have been shaped by political, economic, and technological changes throughout history and have undergone a gradual transition process in line with energy security, reducing external dependency, and sustainable development objectives. This transformation process is examined within five main periods:

1) Early Period (1923–1970): Infrastructure Development and Institutionalization

In the early years of the Republic, electricity production in Turkey was quite limited and largely dependent on coal and hydroelectric sources. During this period, priority was given to establishing the technical and institutional infrastructure of the energy sector. With the establishment of Etibank and the Electricity Research Administration (EİEİ) in 1935, research, investigation, and implementation activities in the energy sector began to be carried out by the public sector. In the 1950s, the establishment of the General Directorate of State Hydropower Works (DSİ) accelerated investments in hydropower plants, and important dam projects such as Keban, Seyhan, and Sarıyar were planned.

2) The Oil Crisis and Period of External Dependency (1970-1990): Search for Sources and Alternatives

The global oil crises of the 1970s brought energy supply security to the forefront of Turkey's agenda. High dependence on fossil fuels highlighted the importance of diversity in energy policies and led to the initiation of the first studies on alternative energy sources such as geothermal and biomass. In 1984, Turkey's first geothermal power plant began operations in Denizli-Sarayköy, marking a pioneering step in the use of domestic and renewable resources. However, during this period, energy investments were carried out primarily under public monopoly, with limited participation from the private sector.

Liberalization and Legal Regulations (1990–2010): Market Opening and Regulatory Reforms

Starting in the 1990s, Turkey adopted liberalization and privatization policies in the energy sector and established the Energy Market Regulation Authority (EMRA) in 2001. The 2003 National Program included the increase of renewable energy sources among its strategic objectives. In this context, the Renewable Energy Law No. 5346, which came into effect in 2005, marked an important turning point in the sector, particularly with the increase in small-scale hydroelectric, wind, and solar energy investments. The first pilot applications for solar energy systems were launched in the Aydın-Didim region in 1998. During this period, while the legal infrastructure was being prepared, the private sector's investment commitments also increased.

3) Strategic Planning and Investments (2010-2020): Increase in Installed Capacity and Efficiency-Focused Transformation

After 2010, there was a rapid increase in Turkey's total installed capacity, and priority was given to renewable energy investments. By the end of 2020, the country's installed capacity reached 95,891 MW. During this process, solar and wind energy projects gained significant momentum, and a notable improvement in energy intensity was achieved. Energy efficiency strategy documents have been implemented in the building, transportation, and industrial sectors. During the same period, large-scale hydroelectric power plants such as the Çetin Dam were commissioned, contributing to the diversification of energy supply.

4) Green Transformation and Sustainability-Focused Developments (2020-2025):

Early Achievement of Targets and International Cooperation

During this period, Turkey surpassed its 2025 solar energy capacity target in 2024, reaching 19.6 GW. Mega-scale projects such as the Karapınar Solar Power Plant demonstrate the technological and economic capacity achieved in renewable energy . Through collaborations with institutions such as the World Bank and the European Bank for Reconstruction and Development (EBRD), billions of dollars in funding have been mobilized for energy transition. Turkey has set a target of 120 GW of renewable energy installed capacity by 2035 and has updated its national energy plans accordingly. Additionally, issues such as net-zero emissions, energy storage technologies, and hydrogen production have been included in the policy agenda as part of efforts to combat climate change.

Turkey's Energy Transition Policies by Year

Turkey's energy transition process has been shaped since the 2000s in line with both national needs and global environmental responsibilities; each policy step has played a critical role in terms of both energy supply security and sustainable development.

1) **2005 – Law No. 5346 on the Use of Renewable Energy Sources in Electricity Production (Renewable Energy Law)**

This law is the first comprehensive regulation aimed at promoting the use of renewable energy sources in Turkey. It introduced fixed-price purchase guarantees to support electricity production from solar, wind, geothermal, biomass, and small hydroelectric sources, thereby increasing investor confidence and simplifying licensing procedures. This law marked the removal of the first major legal obstacle to renewable energy investments.

2) **2010 – YEKDEM (Renewable Energy Resources Support Mechanism)**

Enacted as a continuation of Law No. 5346, YEKDEM ensured the financial sustainability of licensed renewable energy producers by providing state purchase guarantees at a fixed unit price. Thanks to this mechanism, there was a rapid increase in the number of wind and solar power plants, particularly between 2010 and 2020, and significant momentum was gained in private sector investments.

3) **2015 – Signing of the Paris Climate Agreement**

Turkey signed the Paris Agreement, prepared under the United Nations Framework Convention on Climate Change, in 2015 but did not ratify it immediately. During this period, a national contribution statement (INDC) was prepared, which included a target to reduce greenhouse gas emissions by up to 21% by 2030. The signing of the agreement was an important indicator of Turkey's determination to align its policies with international climate policies.

4) **2017 – Implementation of the YEKA Model**

The Renewable Energy Resource Areas (YEKA) model is a public-private partnership model that aims to increase the share of domestic production in production technologies and promote the development of domestic industry by covering large-scale investments. With the first YEKA-GES and YEKA-RES tenders conducted in 2017, Turkey has facilitated technological capacity and know-how transfer by implementing some of the world's lowest-cost renewable energy investments.

5) **2020 – The European Green Deal and its implications for Turkey**

The EU's border carbon adjustment, green economy transformation policies, and commercial sustainability priorities have directly impacted Turkey's export-oriented sectors. In this context, Turkey has developed strategies to reduce its carbon footprint in energy production, transition to green production technologies in industry, and support sustainable supply chains post- . Turkey has formalized this process through the Turkey Green Deal Action Plan (2021).

6) **2021 – Ratification of the Paris Agreement by the Turkish Grand National Assembly**

On October 6, 2021, the Paris Agreement was ratified by the Turkish Grand National Assembly, and Turkey announced its target of achieving **net-zero emissions** by 2053. This development accelerated the alignment of national energy and environmental policies with the climate change perspective and paved the way for green transformation-focused projects at the financing, investment, and planning levels.

7) **2024 – World Bank Turkey Energy Transition Support Program**

Under new agreements with the World Bank, Turkey is investing in new-generation energy technologies, particularly storage technologies, electric vehicle infrastructure, and distributed renewable energy systems. Under the cooperation agreement signed in 2024, the World Bank is supporting Turkey's emission reduction, efficiency, and resilience-focused projects in the energy sector through long-term loans and technical advisory services. This agreement is of critical importance for ensuring financial sustainability in the energy transition and gaining the trust of international investors.

Applications at Different Spatial Scales

Energy transition processes require planning and policy interventions at various levels, from local to international. At the local level, solar and wind energy projects, energy cooperatives, and green building standards are prominent, while at the urban level, emission reductions are targeted through transportation and urbanization policies. At the regional level, energy clusters and the protection of natural areas are ensured, while at the national level, the transition away from fossil fuels is pursued through tools such as energy efficiency, the YEKA model, and carbon trading. At the international level, climate agreements and collaborations aim to limit global warming and build climate-resilient systems.

SPATIAL SCALE	PLANNING PRACTICE/INTERVENTION	TARGETED CHANGE	EXPECTED CHANGE
LOCAL	Site suitability analysis for solar power plant/wind power plant installations, energy cooperatives, green building standards	Reducing carbon footprint, social participation	Settlements powered by clean energy, conscious communities, systems supported by local producers
URBAN	Transportation master plans integrated with electric vehicle infrastructure, energy-efficient building conversion projects, green neighborhood planning	Reducing emissions, reducing transportation-related pollution	Improved air quality, quiet and efficient cities, reduced heat island effect
REGIONAL	Establishment of renewable energy clusters (Wind Energy Valley), integration with regional basin plans	Protection of natural areas and balancing of energy production	Ecosystem-based energy production, minimizing environmental impacts
NATIONAL	National energy efficiency, incentive programs, central planning, determination of the Renewable Energy Resource Area model, regulation of carbon trading systems	Abandoning fossil fuels, reducing social inequalities	Access to affordable energy, carbon-neutral economy
INTERNATIONAL	Cross-border energy cooperation strategies for accessing climate finance funds, active participation in the Paris Agreement and COP processes	Limiting global warming	A sustainable future through international cooperation, climate-resilient systems

Figure 1. Spatial Intervention Levels for Energy Transition.

Energy Transition Policies Affecting Turkey

- Turkey's energy transition has been significantly influenced by global political, environmental, and economic changes over the past fifty years. A comprehensive understanding of these developments reveals how international turning points have shaped national energy policies and strategic orientations.
- The oil crises of 1973 and 1979 exposed the geopolitical risks and supply vulnerabilities associated with fossil fuel dependence, marking a turning point in global energy policy. For Turkey, as for many developing countries, this situation led to increased interest in energy security and diversification and laid the groundwork for long-term structural changes.
- The Brundtland Report, published in 1987, introduced the concept of sustainable development and placed environmental issues on the global development agenda. This concept began to influence energy policy discussions in Turkey in the early 1990s.

- The signing of the United Nations Framework Convention on Climate Change (UNFCCC) at the 1992 Rio Earth Summit institutionalized global efforts to combat climate change and integrated environmental issues into energy governance frameworks. This international agreement marked the beginning of climate-compatible policy-making in countries such as Turkey.
- The 1997 Kyoto Protocol, which introduced binding carbon reduction targets for developed countries, accelerated the expansion of renewable energy investments worldwide. Turkey was not initially committed to these targets, but the protocol's principles laid the foundation for subsequent policy tools aimed at aligning with global decarbonization goals.
- Domestically, Law No. 4628, which liberalized the electricity market and established the Energy Market Regulatory Authority (EMRA) in 2001, marked an important turning point. This signaled the beginning of energy sector reforms and paved the way for private investment, deregulation, and ultimately the development of renewable energy markets.
- The entry into force of the Kyoto Protocol in 2005 also led to the creation of carbon markets and the launch of the European Union Emissions Trading System (EU-ETS). Although Turkey did not join this system, these developments began to influence investment patterns and regulatory expectations, particularly in the context of European integration.
- The Paris Climate Agreement, signed in 2015, marked an important global turning point by making energy transition an official political priority. The agreement aimed to limit global temperature increase to 1.5 °C and identified renewable energy as a key strategic tool for achieving climate neutrality.
- In 2016, China's global leadership in solar and wind technologies reshaped the dynamics of the international renewable energy market. In response to these changes, Turkey launched its first large-scale wind and solar energy investments, including the initiation of the YEKA (Renewable Energy Resource Areas) model.
- Following the COVID-19 pandemic, the European Union launched a "green recovery" process in 2020 with the European Green Deal, promoting climate-resilient development and circular economies. In response, Turkey began preparing a Green Deal Action Plan under the Ministry of Trade to align its export-oriented industries and energy infrastructure with EU climate regulations.
- In 2021, Turkey officially ratified the Paris Agreement and announced its long-term development vision and energy planning framework, integrating decarbonization and setting a target of net-zero emissions by 2053.
- The 2022 Russia-Ukraine war plunged Europe's energy security into crisis, accelerating the transition to renewable energy and highlighting the importance of energy independence. Turkey, which occupies a strategic position between energy-producing and energy-consuming regions, has intensified its efforts in regional energy diplomacy and infrastructure investments.
- In 2023, the International Energy Agency (IEA) reported that, for the first time in history, more than 50% of global energy investments were directed toward renewable energy, signaling an irreversible transition in the global energy landscape that strongly influenced Turkey's domestic agenda.
- By 2025, Turkey's first Climate Law was adopted by the Grand National Assembly, establishing a legal framework for decarbonization, emissions monitoring, climate adaptation, and compliance with international agreements. This legislation marked a historic institutional turning point in Turkey's energy-climate relationship.

- Finally, the 12th Development Plan (2024-2028), adopted in 2025, officially prioritized green and digital transformation as the cornerstones of national development. Strategic issues such as energy efficiency, nearly zero-energy buildings (nZEB), smart urban infrastructure, ESCO (Energy Service Company) models, and regional clean energy corridors have been moved to the forefront of planning and investment agendas, positioning Turkey as a proactive actor in the global energy transition.

Methodology

This study employs a mixed research method to examine the environmental impacts of renewable energy investments in Turkey and assess how these impacts can be managed through spatial planning. Both qualitative and quantitative data analysis techniques have been combined in the study.

The case study method was applied to two important projects in Turkey: the Karapınar Solar Power Plant (GES) and the İzmir Wind Power Plant (RES). These projects were evaluated comparatively across multiple dimensions, from site selection to environmental impacts, levels of social participation, and planning tools. Both projects are situated in different geographical, climatic, and social contexts, representing the diversity of renewable energy investments in Turkey.

Using document and content analysis methods, environmental impact assessment (EIA) reports, planning documents, national energy strategy documents, and local government policy texts were examined. The findings from these documents were systematically evaluated to identify the strengths and weaknesses of the projects in terms of environmental sustainability, social acceptability, and spatial integration.

The comparative analysis method enabled the comparison of practices in Turkey with examples from countries such as Germany, China, Denmark, and the Netherlands. These countries serve as examples for Turkey due to their prominent practices in areas such as renewable energy policies, public participation processes, cumulative impact assessment applications, and landscape planning.

The methods used throughout the study enabled a more comprehensive analysis of the social and ecological impacts of energy investments in line with the principles of spatial integrity, environmental justice, and multi-scale planning.

Main Results

Spatial and National Approaches to Renewable Energy Transition: Turkey and International Examples

Renewable energy transition is a multidimensional process that requires planning and governance at different scales. At the local level, energy cooperatives and site suitability analyses, at the urban scale, transportation and urbanization policies, at the regional level, energy clusters, at the national scale, incentive mechanisms, and international cooperation form the building blocks of this process.

Turkey's Karapınar GES (1,350 MW) and İzmir RES (1,700+ MW) are technically focused projects based on centralized planning. While Karapınar aims to reduce carbon emissions, İzmir RES seeks to balance nature conservation with energy production. However, public participation is limited in both projects.

Germany is achieving transformation through strong citizen participation and a cooperative model under its "Energiewende" policy. China is a leader in energy production with large-scale projects based on central planning. Denmark, on the other hand, prioritizes sustainability through community-based models integrated with local governments.

This comparison highlights the need for Turkey to support its technical achievements with social participation, environmental awareness, and local integration.

	Karapınar Solar Power Plant	Izmir Wind Power Plant	Germany's Energiewende	China Solar Energy Farms	Denmark Energy Systems
Type of Energy	Sun	Wind	Combined (solar+wind+bioenergy)	Sun	Sun+Wind
Purpose	Carbon reduction, energy supply security	Regional energy production, assessment of renewable resource potential	Social energy transition, low-carbon economy	Mega-scale energy production, energy independence	Local production, community-based sustainability
installed power	1350 MW (as of 2023)	1700+ MW (across İzmir; Karaburun, Çeşme, Aliağa, Bergama regions)	60,000+ MW	880 GW (solar capacity as of 2024)	Total of several GW; distributed system supported by microgrids
Scale	Regional (Konya-Hatay axis)	Coastal mountainous areas (especially the Çeşme Peninsula)	National + Regional	Mega regions (e.g., Kubuqi Desert, Gansu)	Neighborhood/town scale, connected to the local network
Legal Framework	Renewable Energy Source Area Model	Renewable Energy Sources (RES) and European Union (EU) compliance	EEG Act (mandatory participation, cooperative incentive)	Central planning + government incentives	Cooperative laws and municipality-supported energy laws
Participation	Meetings, public information processes	Non-Governmental Organizations and public participation are sometimes limited; local reactions have been observed in Karaburun in particular.	Citizen cooperatives (~900), 50% private citizen share	Low public participation, decisions are made centrally	High participation at the neighborhood level, joint investment models
Environmental Impact	Annual reduction of 2 million tons of CO_2	Flora-fauna impacts and visual pollution debates; objections regarding bird migration routes in Karaburun	Local employment, social acceptance, reduction in carbon emissions	Land use change, agrovoltaic trials, nature conservation balance	Energy efficiency + strengthening social ties
Spatial Planning Approach	Early planning and scaled investment model	Strengthening participation processes; selecting appropriate locations in rural areas	Integration of legal participation into planning, social ownership	The requirement to conduct environmental and land analyses prior to large-scale investments	Cooperation with local governments, integration of local energy systems
General Comments	A model example in strategic and technical terms	High local potential; social resistance may develop due to lack of communication with the public.	A pioneer in Europe in terms of participation and transformation, democratic energy transition	Hızlı büyüyen dev model; sürdürülebilirlik için arazi ve tarım planlamasıyla birlikte ele alınmalı	A local system model that is scalable and suitable for socio-technical transformation

Figure 2. Spatial and Managerial Differences in Renewable Energy Systems: Selected Country Examples

What solutions and policies were proposed in the literature regarding planning practices at different spatial scales?

Although renewable energy projects appear environmentally friendly, they carry environmental risks such as spatial incompatibility, habitat loss, disruption of bird migration routes, and visual quality issues (Duru, 2018; Yılmaz & Uslu, 2020). Therefore, energy investments should be evaluated not only from a technical perspective but also in terms of their ecological, social, and spatial dimensions.

Standardization of Spatial Suitability Analyses

Spatial suitability analyses (GIS-based analyses, threshold-synthesis maps, carrying capacity calculations, etc.) used in the site selection process for renewable energy investments are applied using different methods in many projects, creating uncertainty in planning processes. Therefore, standardized spatial suitability analysis methodologies that are valid at the national level and include ecological, socio-cultural, and technical criteria should be developed. This approach is critical for the protection of natural areas, the prevention of land use conflicts, and the integration of energy infrastructure in harmony with nature. The legal regulation of standardized analyses will strengthen coordination among investors, planners, and local authorities.

Cumulative Impact Assessment (CIA)

Environmental Impact Assessment (EIA) processes typically focus on individual projects; however, when multiple energy investments are present in the same watershed or region, cumulative environmental impacts become more pronounced. Cumulative Impact Assessment (CIA) is a multi-scale tool that analyzes the total impact of all existing and planned energy projects in a specific area and predicts the collective environmental pressures these impacts will create. The integration of CEAs into planning processes is essential for protecting ecosystem integrity, preventing habitat fragmentation, and ensuring the sustainability of natural habitats. In this context, CEA reports should be evaluated on a regional basis rather than on a project-by-project basis and should guide planning decisions.

Mandatory Implementation of Participatory Planning Processes

Large-scale infrastructure investments, especially energy projects, have direct consequences for local communities. Therefore, planning processes must be based not only on technical and economic analyses but also on the knowledge, opinions, and approval of the community. Participatory planning strengthens social sustainability by actively involving local governments, civil society organizations, professional associations, and local communities in the decision-making process. This approach reduces social conflicts, increases local ownership, and supports the principle of environmental justice. Participatory practices, which are currently limited to consultation at most in existing legislation, should be made a mandatory and binding stage of planning. Public referendums, information meetings, and consensus-building mechanisms should be legally guaranteed, especially for energy projects in rural areas.

Integrated Energy and Land Use Planning

The independent implementation of energy infrastructure and land use decisions leads to the loss of natural resources, spatial conflicts, and social tensions. Therefore, energy investments and spatial planning processes must be integrated. Multi-criteria site selection models that take into account the interaction of renewable energy areas (SPPs, WPPs, biomass plants, etc.) with agricultural areas, forest areas, water basins, and ecological corridors should be used. This integration will ensure that energy investments are located in a manner that is compatible with nature, socially acceptable, and economically efficient. Planning legislation must include binding provisions for both high-level guidelines and lower-level plans regarding energy investments.

Phased Transition Strategy

In developing countries like Turkey, implementing energy transformation abruptly and at high cost can create social and economic resistance. Therefore, a phased transition strategy offers an interim planning period to reduce fossil fuel dependence while maintaining system security and economic sustainability. The transition process should be supported by energy storage technologies, hybrid systems, low-emission intermediate fuels (e.g., natural gas), grid modernization, and urban energy efficiency measures. Additionally, the strategy should strengthen social acceptance through employment policies, fair transition principles, and public information mechanisms. The stages of this transition should be defined in planning documents, linked to a target year, and measured using performance indicators.

Energy Efficiency-Focused Urban Transformation

Urban renewal projects offer strategic opportunities not only for structural renewal but also for reducing energy consumption and carbon emissions. In this context, solutions such as passive building design, insulation standards, solar energy integration, energy-efficient lighting, and heating systems should be encouraged in transformation areas. Additionally, urban planning decisions focused on energy efficiency should incorporate spatial criteria such as building density, orientation, mass-to-area ratios, and natural ventilation. Green building certifications, carbon footprint calculations, and energy performance indices should be made a legal requirement for local governments to create carbon-neutral neighborhoods and climate-friendly urban areas.

Careful Planning in Coastal, Natural, and Cultural Areas

When renewable energy projects overlap with coastal areas, protected natural areas, or cultural heritage sites, spatial constraints and sensitivity thresholds must be defined. Renewable energy sources and projects based on renewable energy sources that could disrupt the ecological balance in coastal areas should be carefully assessed, particularly in relation to migration routes, lagoons, wetlands, and marine mammal habitats. Protection planning tools should be effectively utilized to safeguard projects that threaten the visual integrity and historical value of cultural landscapes. Additionally, planning processes in these areas must be integrated with international agreements (RAMSAR, BERN, UNESCO, etc.) and Environmental Impact Assessment (EIA) reports.

Climate Law

A Climate Law that establishes a institutional and legal framework for combating climate change in Turkey is of vital importance in terms of providing legal guarantees for national targets and making them binding on all sectors. Under the law, the 2053 net zero emissions target, energy transition plans, carbon trading mechanisms, climate finance regulations, and the climate responsibilities of local governments must be clearly defined. Additionally, making climate impact analyses and risk assessment scenarios mandatory in planning processes will contribute to the creation of long-term resilient settlements. This law also represents a strategic step toward integrating Turkey's international obligations under the Paris Agreement and the European Green Deal into domestic law.

Conclusion

This study demonstrates that the role of cities in renewable energy investments is not limited to determining energy production areas, but also involves a multidimensional responsibility, including the management of environmental impacts, the balancing of social processes, and the promotion of sustainable development goals. Cities also demonstrate that energy transition is not merely a technical issue but also a spatial, social, and governance issue. In this context, energy planning and spatial planning must be carried out in a coordinated manner using an integrated and layered approach.

The success of sustainable energy transition should be measured not only by the amount of energy produced but also by the level of harmony between this production and nature, society, and urban areas. Therefore, participation, transparency, and scientific foundations should be fundamental principles in planning processes, and decision-making mechanisms should be strengthened through multi-stakeholder structures.

In addition, increasing the authority and implementation capacity of local governments is one of the fundamental elements that will enable them to play an active and effective role in this process. Municipalities should be positioned not only as implementers but also as guiding, supervising, and social transformation actors. In this way, cities can become strategic planning actors that guide energy transformation rather than merely being energy consumers.

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Child Friendly Cities and Peripheral Learning: Designing Urban Space as a Pedagogical Tool

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ABSTRACT

This study aims to examine good practises in relation to the effects of the design of child-friendly cities on children's peripheral learning processes. Peripheral learning is the process by which an individual obtains information indirectly from his/her physical and social environment without receiving direct instruction. It is seen that safe, aesthetic, interactive and livable urban areas designed for children increase learning motivation and support cognitive, affective and social development. In this paper, the interaction between the concept of child-friendly cities and peripheral learning is discussed and a pedagogical perspective is proposed in sustainable urban planning. The paper is supported by good examples from different places that can contribute to children's peripheral learning and explains the impact and contribution of these places on children.
Key words: Child friendly city, peripheral learning, urban space

Introduction

Pedagogical Perspective on the Relationship between Children and the City

Modern cities are generally designed with an adult orientation. However, cities are both a living and a learning space for children. Education takes place not only within the classroom, but also within all environmental factors that children interact with. In this context, child-friendly cities are urban learning environments that support not only physical safety but also mental and emotional development (1). A signboard that a child sees on the street, icons in a park, posters on the facade of a science centre or art installations at a station leave a mark on the child's mind and contribute to the learning process. Public spaces where children explore through play, learn numbers through wall paintings, and internalise the concept of direction through shapes on the ground are peripheral learning spaces that support their cognitive and social development. In this paper, child-city interaction will be analysed in the context of peripheral learning, and it is aimed to discuss the design and areas that will support children's learning in the urban environment from a pedagogical perspective. At the same time, examples of good practices in different cities will be analysed to reveal how child-friendly spaces contribute to learning processes.

Methodology

This study was conducted using a qualitative research approach and aims to examine the relationship between child-friendly urban design and children's peripheral learning processes from a pedagogical perspective. The research focuses on understanding how urban environments designed for children contribute to indirect learning. In this regard, the concepts of "Child-Friendly Cities" and "Environmental Learning" were first analyzed theoretically, and the pedagogical and spatial components that support children's learning through interaction with their environment were identified. Subsequently, good practice examples in different cities, primarily in the province of Sakarya, were examined using descriptive analysis and content analysis methods. Each example was evaluated in terms of its contribution to children's cognitive, affective, and social development and its function as a pedagogical urban space. Areas such as Living Street, Traffic Park, Adventure Park, Planetarium, and Science Center were analyzed comparatively to show how design elements and spatial arrangements support children's observation, environmental awareness, creativity, and problem-solving skills. This methodological approach aims to bring together pedagogical theory and urban design practices to reveal how sustainable, inclusive, and interactive urban spaces can function as learning environments for children.

What is Peripheral Learning?

Peripheral learning is the process by which an individual learns indirectly, intuitively and usually unconsciously from his/her physical and social environment without receiving direct instruction. According to Jean Lave and Etienne Wenger's theory of situated learning, when individuals are part of a social environment, they are not passive but active participants who continuously learn from their surroundings (2). 'Peripheral learning' refers to the process by which children, in particular, learn from visual, auditory and physical stimuli in the environment that are outside of conscious focus. Children are engaged in peripheral learning even when they are playing in the park, observing on public transport or studying a mural (2). The integration of child-friendly cities with peripheral learning has the following positive effects: Information Acquisition through Visual and Semantic Stimuli:Signboards, direction signs, public art applications (murals, sculptures), posters and signs with environmental messages in the urban space attract children's attention and develop both aesthetic sensitivity and symbol literacy. Aesthetically organised environments contribute to children's cognitive development by positively affecting their attention and focusing skills (1). Playgrounds and Discovery-Based Learning: Children make sense of the world through play. Children's playgrounds are simple, spiritually and physically developing areas where children can run and play freely in open spaces and utilise their free time. These areas constitute an important part of children's daily recreational needs (3). Games in urban areas can fulfil various functions such as feeling good, learning, accessing data, and participation (4). In child-friendly cities, playgrounds should be designed as educational structures that support not only physical mobility but also problem solving, trial and error, cooperation and creativity skills. Playgrounds with natural elements support the development of creativity and problem-solving skills. Interaction with Nature and Ecological Learning: Vaske and Kobrin (2001) found in their study that children's experiences in nature increase their environmental awareness and knowledge level, which positively affects the shaping of their perceptions (5). Şahin and Dostoğlu (2015), in their study on school buildings, mentioned the benefits to children of designing schools in a way that is associated with fresh air, daylight and scenery, provides sports opportunities, can use the environment as a resource for learning, and supports social development. In child-friendly cities, areas such as parks and gardens where children can connect with nature and grow vegetables and fruits are created and children are helped to empathise with the environment. By creating areas in parks and forests that can be used for lessons, storytelling or nature observations, out-of-school learning areas are increased in cities (6). Space for Independent Movement and Social Learning for All Children: Safe streets, pavements and pedestrian zones where children can move independently are critical for the development of their social skills. Traffic-free playgrounds are located in safe areas. Suitable areas are created for all children (including physically disabled individuals). For this reason, the principle of 'design for all' is adopted within the scope of 'usable space' arrangement by creating healthy environments for children. When designing children's playgrounds that physically disabled children can easily use, the approach of creating spaces for all children, not only for the disabled, is adopted. Regardless of the disability, the basic needs of children are the same (7,8). Designing In Accordance With The Needs Of Age Groups: The periodic needs of 0-3 years, 4-6 years, 7-12 years and adolescent groups should be taken into consideration and social environments should be designed to meet their needs in the city. For the developmental period of 0-6 years, arrangements such as colourful painted floors made of rubber, soft materials, colourful walls, low-level benches, sound-making walkways and different textured surfaces enable children to experience their environment safely. In the 7-12 age period, environmental stimuli such as thematic areas, nature-based discovery trails, observation areas (such as birdhouses, botanical gardens), pavements designed with mathematical shapes or operations support children's thinking, observation and experience skills. These contributions ensure that peripheral learning creates not only knowledge but also sensitivity, responsibility and awareness in the child's mind. A child-friendly city is actually a learning ecosystem where every structure around the child is a 'teacher'.

Good Practises:

Living Street: Serdivan Municipality has implemented the 'Living Street Project' in order to transform city streets into livable spaces for children and their parents. With the start of the project, which also includes the Social Development Centre, it is aimed to transform various streets of the city into child-friendly public spaces (9). It supports children's indirect learning by offering a design that does not teach children through the environment, but makes them develop behaviours and concepts in the living space implicitly.

Traffic Parks: Signs such as traffic lights, road lines, stop, go, pedestrian priority signs develop children's ability to recognise and make sense of symbols. They learn street culture, use of public space and social skills such as empathy (with other drivers and pedestrians) through observation and experience. They are environments that teach rules, responsibilities, social communication and safe living behaviours without teaching them, and provide learning through social clues.

Karaman Barrier-Free Park: There are children's barrier-free playgrounds (10). The park also serves the discipline of "non-discrimination", one of the main principles of child-friendly cities.

Karaman Adventure Park: Adventure Park consists of tracks such as trust wall, climbing tower, tree path, multiple walking tracks, giant stairs and tree steps. Children will contribute to the development of daily life skills such as what can be done in natural environment conditions. Visual symbols and maps placed in the forest area will improve visual memory and perception skills. In addition, it supports learning by experimenting and experiencing, that is, developing communication skills, developing self-confidence and courage, developing skills such as risk-taking and focusing (11).

Planetarium: In the planetarium, the artificial image of the sun, stars, planets and all other celestial bodies is projected onto the dome-shaped ceiling with a special system. In the planetarium, the depths of space can be watched exactly.

Kocaeli Science Centre, Kocaeli: It is a centre with experimental and hands-on activities, encouraging visitors to experiment and explore. By exploring the centre in free movement, they are exposed to different experiences according to their individual interests. The fact that colours, writings and figures are designed in a fun and remarkable way attracts children's attention, which strengthens children's peripheral learning skills by triggering their curiosity without distracting their attention (12).

Menemen, Izmir: Children's Play Village is an effective outdoor education area that supports the peripheral learning approach in children's cognitive, emotional and environmental awareness development. Eindhoven, Holland: Playgrounds are designed as innovative learning environments to support children's physical, mental and social development and peripheral learning (13).

COMPARATIVE ANALYSIS TABLE

Implementation Area	**Place**	**Type of Learning**	**Skills & Outputs**
Living Street	Sakarya, Türkiye	Peripheral, Social, Visual	Making Observation, Motor Skills Development
Traffic Park	Sakarya, Türkiye	Peripheral, Experiental, Social, Visual	Learning Street Culture, Social Skills Through Observation and Experience
Karaman Barrier-Free Park	Sakarya, Türkiye	Peripheral, Physical, Nature-based, Ecological, Social	Development of Sensory and Social Skills, Developing Autonomous Learning Skills, Motor Skills Development
Karaman Adventure Park:	Sakarya, Türkiye	Peripheral, Physical, Experiental, Ecological, Collaborative	Taking Risk, Making Observation, Motor Skills Development

Planetarium	Sakarya, Türkiye	Peripheral, Visual, Conceptual	Making Observation, Developing Sense of Curiosity, Gaining Astronomy Awaraness
Kocaeli Science Centre	Kocaeli, Türkiye	Peripheral, Experiental, Informal	Scientific Thinking Skills, Developing Exploring and Problem-Solving Skills, Developing Sense of Curiosity
Menemen Children's Play Village	İzmir, Türkiye	Peripheral, Experiental, Conceptual	Emotional, Cognitive, Environmental Awareness Development
Spiel de Park	Einhoven, Holland	Peripheral, Experiental, Ecological	Physical, Mental and Social Development, Environmental Awareness

Main Results:
Child-friendly cities, which support children to learn from their environment, are not only places where children can physically move freely, but also spaces that support their affective, cognitive and social development. These areas, where peripheral learning is naturally supported, are powerful learning scenes that build not only the present but also the future identity of the child. In the good practices analysed in Sakarya, its surroundings and around the world, areas that support children's peripheral learning transform the physical and institutional environment of the city into rich learning spaces for children. These projects enable children to learn about sustainability, nature, traffic safety and scientific curiosity through direct observation and experience.

Conclusion:
Designing cities in a way that enhances children's learning potential enables them to acquire life skills through environmental learning. Urban space is both a play, a discovery and a teaching environment for children. In this context, child-friendly cities should be not only livable but also learnable. Areas with peripheral learning potential should be consciously planned to enrich children's relationship with space.

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Young People's Spiritual Quest with the Loss of the Sacred in the Modern City

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ABSTRACT

In today's cities, where modernization and urbanization are rapidly advancing, the visibility and social function of sacred spaces and religious symbols in public areas are gradually diminishing. In traditional societal structures, sacred spaces were not merely places of worship; they also served as the spatial embodiment of social memory, belonging, and cultural identity. However, in today's world, individualization, digitalization, and a consumption-driven lifestyle are undermining the representation of the sacred in public spaces. In an age of increasing individualism, digitalization, and speed, younger generations are moving away from traditional religious structures and rituals and turning to alternative ways of addressing their sense of spiritual emptiness. For young people, meditation spaces, nature walks, digital worship groups, silent retreats, urban retreats, and mindfulness practices have become ways of establishing a new relationship with the sacred. Young people, moving away from traditional places of worship, are constructing new types of meaningful spaces and seeking to fulfill their spiritual needs in this way. An assessment conducted within the framework of Charles Taylor's theory of secularization, Mircea Eliade's approach to sacred spaces, and Henri Lefebvre's urban sociology sheds light on the transformation of the sacred in terms of space. As sacred spaces become less prevalent, personal and alternative spaces are finding new counterparts. This paper demonstrates that the sacred has not been completely erased from urban life, but rather has been reproduced by young people in different digital and physical spaces. For this reason, urban planning must take into account not only physical needs, but also emotional and spiritual needs.

Keywords: Sacred space, Youth, Spirituality, Secularization

Introduction

In traditional societies, religion plays a decisive role as a fundamental element shaping individual and social life.(1) In almost every period, sacred places have played a central role in the construction of social memory, belonging, and cultural identity, beyond being merely areas where worship practices are carried out.(2) Religious beliefs, cultural and moral norms, and feelings of individual and social belonging are among the primary factors in the establishment and development of cities.(10) In Islamic cities, mosques and other religious buildings form the central public space, while traditional Ottoman cities were also shaped around religious structures. In today's world, where modernization and urbanization are rapidly advancing, profound transformations have taken place in all layers of social life.(1) Modern cities, as areas where secularization, individualization, and consumer culture are concentrated, have reduced the visibility of the sacred in public life and weakened the relationship between religious structures and individuals.

Classical secularization theorists predicted that the process of modernization would gradually diminish the importance of religion and mythological and similar supernatural structures. According to these theories, metaphysical beliefs will weaken and lose prestige as a result of the differentiation and rationalization of societies. However, religiosity will not only lose its decisive influence on social institutions, but will also undergo a significant shift in the individual's life.(7) In the postmodern era, although individuals have shifted in their lives, it is seen that the representation of the sacred in public spaces and its social function (12) have undergone changes and taken on a new form, particularly due to the effects of individualization, digitalization, and consumption-oriented lifestyles. To describe this new phenomenon, concepts such as "new religions," "cult," "esoteric movements," "new religious movements," "new age beliefs," and "new age spirituality" are used. It is noteworthy that similar forms of belief have become visible in modern Turkey in particular.(1) This study aims to reveal how the sacred has not been completely erased in a spatial and symbolic sense, but rather transformed through new digital and physical spaces.

Methodology

This study was conducted using a qualitative and conceptual research approach to understand young people's attitudes toward the sacred and the search for spirituality in modern urban life. A comparative and interpretive analysis was conducted based on existing literature, theoretical approaches, and current examples to examine the transformation of the sacred in the modern city. In this context, Mircea Eliade's understanding of sacred space, Charles Taylor's theory of secularization, and Henri Lefebvre's sociology of space formed the basic theoretical framework of the study. The study was conducted based on open-source academic literature and observational findings; it aimed to reveal how the decline in the visibility of the sacred in the public sphere, due to the effects of secularization, individualization, and digitalization in modern cities, has transformed the ways in which young people experience spirituality.

Main Results

The main findings of the report reveal the effects of modernization, secularization, and digitalization on traditional forms of religiosity and how individuals' spiritual quests find new areas of expression. These areas of expression can be understood in a more theoretical context within the framework of Mircea Eliade's approach to sacred space, Charles Taylor's theory of secularization, and Henri Lefebvre's urban sociology. Although Eliade emphasizes places where the sacred acquires a special meaning by separating itself from the profane (4), this situation takes on a different dimension today with young people's re-creation of the sacred. According to Eliade, sacred places serve as a bridge between the physical and spiritual worlds. These places are also exalted in a spiritual sense as areas containing various symbolic elements. Virtual sacred spaces, despite not having a physical presence, can also offer individuals the opportunity to achieve spiritual peace.(9) According to Taylor, it emerges in different forms in individual life by withdrawing from the sacred public sphere. Secularization is defined as a process in which religious beliefs, practices, and institutions lose their social significance. This process causes religion to become private rather than external.(13) Lefebvre, on the other hand, examines the relationship between space and social and cultural processes and how these spaces are produced and transformed, arguing that new spaces are shaped according to different socioeconomic and cultural conditions.(3) These three theoretical approaches provide a comprehensive framework for understanding how the sacred manifests itself in different ways in today's cities, how individuals' religious experiences are being restructured, and how space is being socially transformed in this process. Based on this theoretical foundation, how sacred space and the search for spirituality are being reshaped can be better expressed under the following headings.

Secularization and the Reshaping of Religiosity; Although classical secularization theories predicted that religion would lose its importance in social life with modernization, it is seen that religion continues to exist in different forms in postmodern societies, despite the claim that religion has lost its decisive role and sanctity. In the social science literature, these new forms of religiosity are referred to as "new age beliefs," "new religious movements," or "the individualization of religion." As Linda Woodhead points out, secularization theories seem unable to explain this change in religiosity. It can be argued that with the decline of institutional religiosity and religious knowledge, individuals are increasingly turning to new forms of religiosity. Indeed, a study has found that people with a high level of religious knowledge are less inclined to embrace new beliefs.(1) This change causes people to transform not only their belief systems, but also the spaces where they experience and interpret these beliefs. Thus, a process begins in which sacred spaces are reproduced on both a physical and symbolic level, and the sacred begins to find new spatial counterparts in modern cities, independent of traditional structures.

The Manifestation of the Sacred and Spatial Transformation; Mircea Eliade's approach to sacred space focuses on the "manifestation" (hierophany) and continuity of the sacred rather than its loss. According to Eliade, the sacred is the opposite of the non-sacred and manifests itself in various forms. "Once a place has been sanctified, it is unlikely to lose this characteristic," and sacred places can be transferred from one culture to another. The history of all religions consists of the accumulation and continuity of manifestations of the sacred. The manifestation of the sacred emerges when a place, person, object, or time rises from the ordinary to an important position. This situation presents itself as a process of "re-sacralization" that can pave the way for the development of religiosity in different forms with the weakening of traditional religious structures.(8)
Within the framework of Henri Lefebvre's urban sociology, it is emphasized that sacred spaces are not static structures but rather undergo transformation alongside social change, in line with the idea that the city is a social production site that is constantly being reshaped. With modernization, the traditional order of cities and the concept of development centered on sacred spaces have given way to rational forces. The transformation of public space is evident, for example, in the attempt to replace mosque-centered settlements with squares. However, even if sacred spaces cannot find a place in the public sphere, they have begun to take on new forms of expression in individual and digital spaces.(5) Therefore, sacred spaces are formations that are fixed and unchanging, yet reshaped by social transformations and acquire new meanings in different periods and contexts. In this sense, the sacred continues to exist in modern cities by finding new spatial counterparts at both the individual and digital levels.

The Spiritual Quest of the Younger Generation and Alternative Spaces; Younger generations are loosening their ties with traditional religious institutions while continuing their spiritual quests in new areas. A study conducted on emerging adults (aged 18-29) studying at Sakarya University shows that university youth have a "new spiritualist" understanding of religion that is distant from traditional-institutional religious understanding, questions religious authorities, and prioritizes individuality. This new trend toward spirituality is dynamic, open to change, and temporary, emphasizing individual interpretations of religion rather than the formalism of traditional religiosity. Young people find current interpretations of religion rigid and are open to new interpretations of religious issues. Additionally, some young people perceive morality as an area independent of religion, which is another reflection of this new spiritualism.
When the younger generation evaluates the legends or stories of sacred places as "mythical narratives" and questions why they do not occur in today's conditions, it shows that they maintain a certain distance from institutional religious approaches and have ideas about changing traditional religious thought.(14)
New age beliefs are generally used to describe individual hybrid belief forms that are not centrally organized, lack authority, and focus on personal development. In this context, practices such as astrology, meditation, and yoga are related to individuals' levels of religiosity. (1) Practices such as silent retreats and mindfulness exercises can also be carried out through virtual meditation sites that offer the opportunity to achieve spiritual peace. (11) Nature walks and nature-based spirituality can be defined as unconscious environmentalism movements

inherent to the culture to which people belong, based on the concept of "implicit environmentalism." This concept is related to feelings toward a place and the emotional connection formed with it. Natural elements such as mountains, rivers, trees, or caves that are considered sacred are becoming new "sacred" spaces that respond to people's spiritual quests.(11) This situation shows that younger generations' ways of redefining the sacred are shaped around individual experience, connecting with nature, and digital practices, and that they sanctify new spaces that can generate personal meaning and emotional attachment rather than traditional spaces.

Digitalization and the Reproduction of the Sacred; The digitalization process has transferred concepts and manifestations related to sacred spaces to various platforms ranging from games to movies, social media to the virtual universe. Virtual sacred spaces are areas that do not have a physical presence but are created through digital platforms. Online church services, online meditation sessions, and virtual community meetings are examples of this. Social media is also being effectively utilized for missionary activities, facilitating the transfer of sacred texts to the digital environment. These developments demonstrate that religion is no longer confined to physical spaces but is developing new forms of existence in the digital realm. Experiences in virtual worlds can be real and meaningful for users because relationships and communities can exist there.(11) However, this digital sacred experience cannot fully replace physical rituals and body-based worship practices, revealing that the spatial dimension of spirituality has not completely disappeared, even though it has undergone a transformation.
In his book Virtual Religion, Mehmet Haberli states that digital technologies are not merely a means of transmitting religion, but also serve as an environment that reshapes and transforms the sacred. According to him, worship practices, online community-building processes, and virtual sacred spaces that emerge in the digital environment not only offer alternatives to the experiences provided by traditional physical spaces but also become spaces where the sacred is reproduced at both the individual and collective levels. As Haberli emphasizes, digitalization does not strip the sacred of its spatiality but rather relocates it to a different space, enabling new sacred space experiences rooted in emotion, belonging, and meaning.(6)

Conclusion

It is evident that the transformation of sacred spaces in modern societies is not a linear process of decline, but rather a cyclical one that paves the way for the development of new spaces. Although the public function of traditional places of worship has weakened, the search for spirituality continues, and this search paves the way for the formation of new sacred spaces in both physical and digital environments. This transformation requires us to consider not only technical infrastructure in urban planning, but also people's search for meaning, their need for silence, and their collective spiritual experiences.
For this reason, integrating quiet areas, spiritual meeting places, public non-worship social spaces, and digital spiritual platforms into the urban fabric can enable younger generations in particular to reconnect with the city and express themselves. The paper argues that this transformation also presents an opportunity to strengthen the spiritual dimension of urban resilience, highlighting that increasing young people's participation in urban decision-making processes can lead to more inclusive and meaningful urban lifestyles.

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Smart City Security: An Explainable AI Methodology for Identifying Key Elements in DoS and Spoofing Attack

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ABSTRACT

Smart city devices offer significant benefits to urban environments, but their susceptibility to cyberattacks, particularly DoS (Denial of Service) attacks, raises substantial security concerns. Understanding the factors that contribute to these attacks is essential for developing robust detection mechanisms. This paper focuses on the application of Explainable Artificial Intelligence (XAI) to identify the most impactful features in detecting DoS attacks on smart city devices. Using SHAP (SHapley Additive exPlanations) values, we interpret the contribution of various features within the CICIoV2024 dataset to model predictions, providing transparency in how the detection model identifies potential threats. By analyzing SHAP values, we pinpoint key features that drive predictions, offering insights into the security risks faced by smart city devices. The study demonstrates that SHAP-based XAI methods enable a deeper understanding of attack patterns and their key indicators, thereby enhancing the interpretability of security models. This paper highlights the potential of XAI, particularly SHAP, in enhancing the effectiveness of intrusion detection systems for smart city environments, thereby ensuring improved protection against DoS and spoofing attacks while providing clear explanations for security professionals to take action. The experimental analysis using the CICIoV2024 dataset reveals the significant impact of key features in detecting these attacks.

Key words: Smart City, Explainable AI, Artificial Intelligence, SHAP, DoS, Machine Learning.

Introduction

A smart city is an urban area that uses advanced technologies to enhance the quality of life for its residents and improve urban efficiency. These cities leverage digital tools to optimize resource management, enhance services, and promote sustainability [1, 2]. IoT devices play a key role in smart cities. They include sensors, smart meters, and connected appliances that collect real-time data to improve everything from energy efficiency to traffic management [3]. The Internet of Vehicles (IoV) is a crucial part of IoT in smart cities. It connects vehicles to each other and to infrastructure. Utilizing IoV technology helps reduce traffic congestion, enhance safety, and optimize transportation networks. These technologies significantly impact urban environments, making them more efficient, sustainable, and safer for residents [1,4].

Table 1. IoV Applications in Smart Cities

IoV Applications in Smart Cities	Sample IoT Devices
Traffic Surveillance	Smart cameras, Traffic sensors, and Drones
Collision Prevention	Proximity sensors, Radar sensors, LiDAR
Self-Driving Cars	Autonomous vehicle sensors, Cameras, LiDAR, and GPS systems
Green Navigation	Smart traffic lights, GPS systems, and Traffic management sensors
Driver Support Technology	GPS navigation systems, Lane-assist sensors, Adaptive cruise control
Intelligent Lighting Control	Smart streetlights, Motion sensors, Light sensors
Accident Analysis	Vehicle cameras, Crash detection sensors, GPS systems
Emergency Operations	Vehicle-to-infrastructure (V2I) communication, Emergency vehicle sensors, GPS
Adaptive Traffic Lights	Smart traffic signals, Traffic flow sensors, Cameras
Connectivity and Entertainment	In-vehicle Wi-Fi, Bluetooth devices, Connected infotainment systems
Pedestrian Safety	Pedestrian detection sensors, Smart crosswalks, Traffic cameras
Predictive Maintenance	Vibration sensors, Wear-and-tear sensors, Diagnostics tools

Smart cities face numerous challenges, including data privacy concerns, cybersecurity threats, and the complexity of managing interconnected systems [5]. Two of the most significant threats are Denial of Service (DoS) attacks and spoofing attacks [6]. DoS attacks can overwhelm smart city infrastructure by flooding it with malicious traffic, disrupting critical services and causing widespread system failures. In the context of IoT and IoV, DoS attacks pose an even greater risk due to the interconnectedness of smart devices and vehicles. Attackers can target communication networks, disrupt vehicle-to-infrastructure interactions, and create chaos in transportation and urban management systems [7]. Similarly, spoofing attacks, where malicious actors impersonate legitimate devices or users, can deceive IoT and IoV systems, leading to unauthorized access, data manipulation, or false information being fed into critical systems. These attacks can compromise the integrity, efficiency, and safety of smart city operations, making robust detection and security measures essential to safeguard against these evolving cyber threats [8].

To address the challenges of cybersecurity in smart cities, particularly DoS and spoofing attacks, machine learning (ML) and artificial intelligence (AI) offer powerful solutions [9]. These technologies can help detect anomalies and identify potential threats in real-time, improving the ability to respond to attacks swiftly. Explainable AI (XAI), particularly through tools like SHAP (SHapley Additive exPlanations), provides further benefits by making the decision-making process of AI models transparent and understandable [10]. SHAP helps to identify which features are most influential in detecting DoS attacks, allowing security teams to better understand the underlying causes of suspicious activity. By leveraging these tools, smart cities can enhance their defenses against cyberattacks, ensure more effective intrusion detection, and create more resilient systems for managing critical infrastructure [11].

In this study, we use SHAP as an XAI tool to identify the key features responsible for detecting DoS and spoofing attacks in IoV systems. SHAP allows us to analyze the impact of these features and assess their severity, providing clear insights into the decision-making process behind attack detection. The analysis is based on the CICIoV2024 dataset [6], which serves as a benchmark for IoV cybersecurity solutions. This dataset includes three main categories: benign, DoS (Denial-of-Service), and spoofing, with the spoofing category further divided into four variants—Steering Wheel, RPM, Gas, and Speed. The dataset was created through experiments on a 2019 Ford vehicle, where five types of attacks, including spoofing and DoS, were executed via the CAN-BUS protocol. These attacks were performed on the vehicle's Electronic Control Units (ECUs) without putting any occupants at risk, ensuring the safety of the testing process. The CICIoV2024 dataset provides an in-depth view of intra-vehicular communications, which is crucial for developing more secure IoV systems. To evaluate the effectiveness of the attack detection, we employed eight machine learning algorithms: AdaBoost, J48, Logistic Regression, Multilayer Perceptron, Naive Bayes, Random Forest, and Random Tree. The primary contributions of this research include the establishment of a realistic benchmark dataset for IoV cybersecurity, the application of SHAP for feature identification and impact analysis, and the exploration of various machine learning techniques to improve IoV security. By laying the groundwork for future IoV security research, this work helps enhance detection systems and optimize machine learning models to defend against cyberattacks in smart city environments.

The paper is structured as follows: Section 2 provides a review of related work on IoV cybersecurity, focusing on DoS attacks, machine learning techniques, and explainable AI methods, particularly SHAP. Section 3 introduces the CICIoV2024 dataset, describing its creation, the types of attacks it includes, and its role as a benchmark for IoV cybersecurity research. Section 4 explains the methodology, including the use of SHAP for feature extraction, impact analysis, and the assessment of feature severity in DoS attack detection. Section 5 covers the experimental setup, detailing the machine learning models, data preprocessing, and application of the CICIoV2024 dataset in the analysis. Section 6 presents the results and discusses the effectiveness of SHAP in identifying key features and the performance of the detection system. Finally, Section 7 concludes the paper, summarizing the findings and suggesting directions for future research in IoV security and XAI applications. We will provide further details of these sections during the complete paper submission.

Literature Review

The importance of IoT devices has a great impact on smart cities. IoV technologies are among the most efficient additions to IoT, bringing significant benefits such as improved urban efficiency and enhanced quality of life. However, newly emerging technologies are still vulnerable to various cyberattacks listed in Table 2 [12]. Protecting IoT devices that bring the idea of a smart city requires them to be protected from attacks.

Several works have been found where researchers have developed defense mechanisms to protect IoV devices from these cyber attacks. Among them, one of the most widely used methods is creating an IDS to check the traffic for abnormal activities and take necessary actions. These IDS systems can be categorized into two types: centralized and decentralized. Centralized IDS processes all data at a single central server, making it easier to manage but less scalable. In contrast, decentralized IDS distributes data processing across multiple nodes, offering better scalability and fault tolerance, but increasing complexity.

Centralized IDS has been widely used in IoV for analyzing and processing data from vehicles and infrastructure. For example, the DeepRed HypInv method [13] achieved an accuracy of 92.50% and an F1-score of 91.24%, focusing on inter/intra-vehicle communication in a centralized system. Image Classification with Transfer Learning-based Fine Tuning [14] demonstrated impressive results with an accuracy of 99.89% and an F1-score of 99.89%, utilizing ensemble learning among fine-tuned CNNs. Similarly, Deep Transfer Learning (CNN and DNN) [15] achieved an accuracy of 97.96% and an F1-score of 82.50%, focusing on inter-vehicle detection. Tree-based methods Stacking Ensemble [16] achieved high performance with an accuracy of 99.87% and an F1-score of 99.87%. LSTM with MLP CNN [17] showed an accuracy of 99.65% and an F1-score of 98.26%, focusing on inter-vehicle communication. LR, NB, DT, RF, AdaBoost, and XGBoost [18] delivered an accuracy of 98.20% and an F1-score of 98.20%. The Attention-based RNN LSTM Auto-encoder [19] achieved 98.88% accuracy and an F1-score of 98.80%. CNN feature extraction with neural network classifiers [20] showed 95.33% accuracy and 92.66% F1-score. Finally, Gradient Boosting with Log Ratio Scaling [21] achieved 99.90% accuracy and an F1-score of 99.80%, focusing on inter/intra-vehicle systems.

Decentralized IDS methods have also been explored to enhance security by distributing the processing load across multiple nodes. GRU RF Ensembler [22], a decentralized method for intra-vehicle detection, achieved an impressive accuracy of 99.52% with an F1-score of 99.65%. LSTM with Federated Learning [23] also achieved a good performance with an accuracy of 95.17% and an F1-score of 92.12% for intra-vehicle security. DNN with Federated Learning and Blockchain [24] focused on inter-vehicle systems, achieving an accuracy of 93.50% and an F1-score of 92.80%. Transformer Networks [25] used encoder-decoder positional and temporal feature extraction for decentralized inter/intra-vehicle communication, achieving an accuracy of 94.85% and an F1-score of 93.13%. In another decentralized approach, Random Forest [26] achieved remarkable results with an accuracy of 99.91% and an F1-score of 99.89%. The Deep CNN [27] method, focusing on intra-vehicle security, also performed well with an accuracy of 99.84% and an F1-score of 99.91%. These decentralized methods typically prioritize federated learning and blockchain to improve security and data privacy across distributed systems.

Several XAI methods are used to detect attacks on IoVs. For example, [28] proposed an explainable deep learning framework utilizing the SHAP mechanism to increase the transparency and resilience of deep learning-based IDS in IoT networks. The experimental results demonstrated strong performance, achieving 99.15% accuracy and an F1 score of 98.83%, highlighting its effectiveness in defending IoV networks from complex cyberattacks. [29] conducted an extensive review of XAI approaches in data-driven and knowledge-aware scenarios like Intelligent Transportation Systems (ITS), providing valuable insights into state-of-the-art evaluation metrics and deployment applications, enriching the design of future XAI systems. [30] introduced a novel VisExp approach to IDS for in-vehicle networks, focusing on detecting and mitigating CAN bus attacks, which showed promising results, making it a potential candidate for IoV attack detection. Authors in [31] integrated ANFIS with human-computer interface platforms to enhance the understanding of UAV behavior, demonstrating the potential of ANFIS for XAI development. [32] developed a novel XAI framework applicable to IoT, including IoV, ensuring robust explanations for IDS decisions in detecting and mitigating attacks by incorporating SHAP and RuleFit models into deep neural networks for better transparency and trust. Finally, [33] proposed a majority vote ensemble approach combined with recursive feature elimination-extreme gradient boosting, which improved accuracy, F1-score, and recall while reducing the miss rate, compared to previous techniques. These studies showcase the growing use of XAI methods to enhance attack detection, transparency, and trust in IoV security systems.

IDS methods, whether centralized or decentralized, are crucial in detecting attacks within IoV systems by analyzing traffic and identifying anomalies. This study highlights the significant potential of SHAP-based XAI methods in offering a deeper understanding of attack patterns and their key indicators, which enhances the interpretability and transparency of security models. The paper underscores the value of XAI, especially SHAP, in improving the performance of intrusion detection systems within smart city environments, ensuring better protection against threats such as DoS and spoofing attacks. Through experimental analysis using the CICIoV2024 dataset, this work showcases the impact of key features in accurately detecting these attacks, providing security professionals with more transparent, actionable insights to respond to and mitigate cyber threats effectively.

Table 2. Categorization of Attacks in IoVs

Attack Category	Attack Type	Security Target
DoS/DDoS	Overloading the network with interference packets	Availability
Modification Attack	Alter the information sent to/received from Infrastructure	Integrity
Selfish	Refuse to cooperate in sharing information	Availability
Impersonation	Claiming multiple/single identity(s) to disturb the network	Authentication
Eavesdropping	Sniffing data and intercepting communication between two nodes	Confidentiality
Routing	Malicious changes in the routing table	Availability
Phishing	Pretending to be an authorized node to gain access to private data	Authentication
Rogue Updates	Sending malicious updates to the vehicle	Availability
MITM	Controlling data transmission between communicating nodes	Confidentiality
Replay	Intercepting and re-sending web requests	Authentication
DoS	Occupying the network and providing service overflow	Availability
Eavesdropping	Sniffing broadcast data from CAN bus or other networking protocols	Confidentiality
Spoofing	Injecting invalid messages into the CAN bus	Integrity
Fuzzing	Sending random CAN frames to ECUs	Integrity
Falsifying	Modifying the CAN packet payload with incorrect values	Integrity

System Structure

The The structure of the proposed system begins with the collection of IoV traffic data from the CICIoV2024 dataset [ref]. This dataset is a comprehensive collection of intra-vehicular communications designed to simulate a variety of cyberattacks targeting IoV systems. It specifically focuses on benign traffic as well as two major types of attacks: Denial of Service (DoS) and spoofing attacks. The spoofing attacks are further categorized into four distinct variants: Steering Wheel, RPM (Revolutions Per Minute), Gas, and Speed. These attacks were executed on a 2019 Ford vehicle equipped with all necessary Electronic Control Units (ECUs), ensuring a realistic simulation of IoV operations. To ensure the integrity and accuracy of the machine learning models, the dataset is split into two parts: 80% for training the models and 20% for testing and validation. The data is available in multiple formats, including binary, decimal, and hexadecimal, providing flexibility for different machine learning techniques. The process of dataset generation, including the execution of attacks and the collection of traffic data, is depicted in Figure 1. This setup forms the foundation for evaluating the effectiveness of IDS models in identifying and mitigating IoV cybersecurity threats.

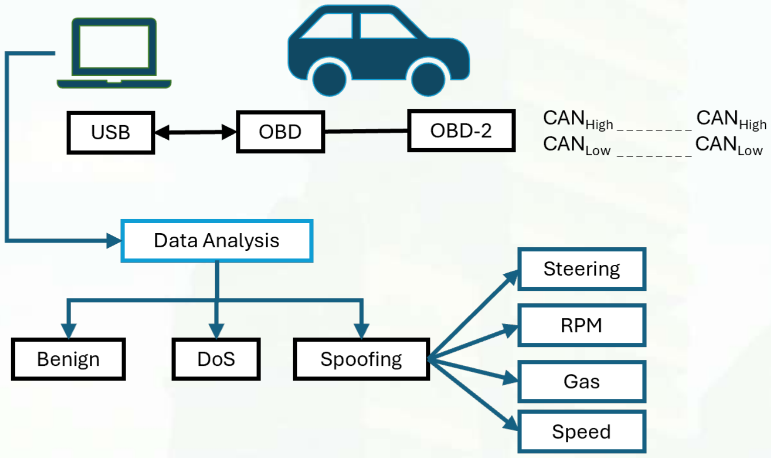

Figure 1. The structure of the CICIoV dataset 2024 [6]

In the next phase, eight different machine learning algorithms are applied to assess the performance of attack detection. These algorithms include AdaBoost, J48, Logistic Regression, Multilayer Perceptron, Naive Bayes, Random Forest, and Random Tree, which are implemented using the Weka tool. Each algorithm is trained and tested on the prepared dataset to evaluate its effectiveness in identifying and classifying benign traffic and various attack types. The goal is to determine which machine learning models perform best in distinguishing between normal and malicious traffic, thereby improving the overall security of IoV systems.

Finally, to enhance the interpretability and transparency of the detection models, Explainable AI (XAI) techniques, specifically SHAP (SHapley Additive exPlanations), are employed. SHAP is used to explain the impact of each feature on the model's predictions, providing insights into the most influential factors for detecting DoS and spoofing attacks. This enables security professionals to better understand how the machine learning models identify attacks and assess their severity. The overall structure and flow of the proposed system, from data preprocessing to attack detection and explanation, is illustrated in Figure 2.

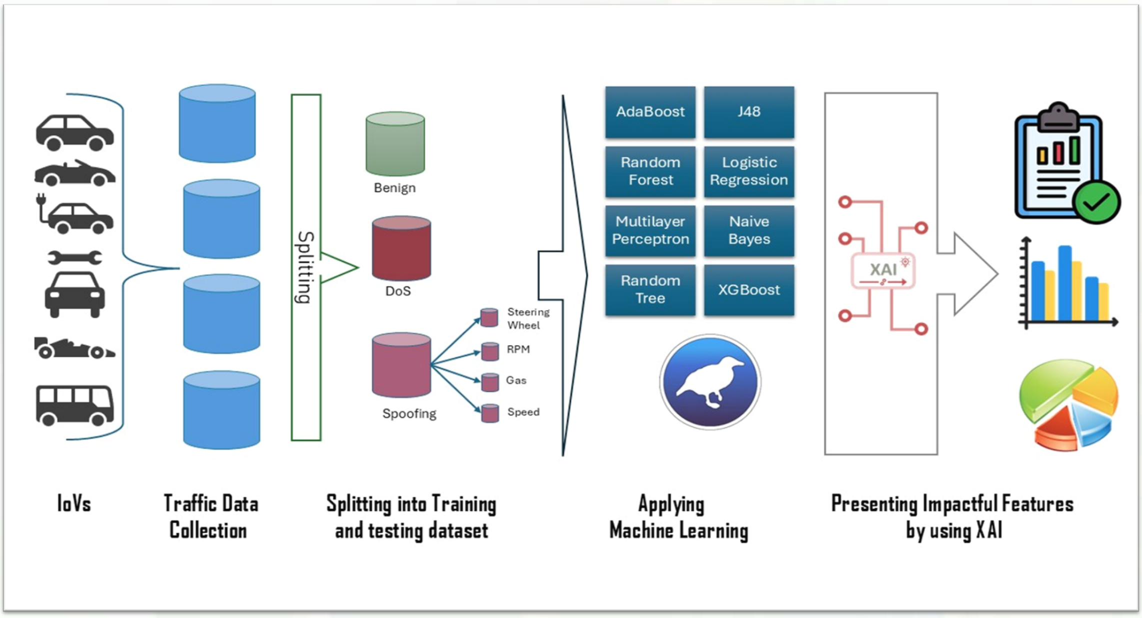

Figure 2. Graphical Abstract of The Proposed Model

Table 3 presents a configuration for performing spoofing attacks on the CAN Bus network, a crucial communication system in IoV (Internet of Vehicles). It highlights how specific bytes, like CAN ID and data bytes (D0 - D7), are manipulated to inject false data, leading to system vulnerabilities and potential risks. The table lists various vehicle parameters such as steering wheel position (SW), engine RPM (Revolutions Per Minute), vehicle speed, and gas pedal position. By altering the values of these bytes, attackers can trick the vehicle's systems into responding to incorrect data, such as a falsely reported steering angle or engine speed. This manipulation can have severe consequences, such as miscommunication between vehicle ECUs, impacting safety features, navigation, and overall vehicle control. The goal of such spoofing attacks is to interfere with normal vehicle operation by injecting misleading information into the system, thereby compromising the integrity and safety of the vehicle's operations.

To execute the spoofing attack, we targeted specific data bytes that control critical vehicle parameters. For example, the steering wheel position is encoded in D0, D1, and D2. The attacker can manipulate D0 to change the steering wheel position, such as altering the value from its normal reading to 0x84 to simulate a 90-degree turn. Similarly, RPM (engine speed) is controlled by D3. By manipulating D3, an attacker can simulate engine RPM data, such as setting it to 0xA0 0x0F (representing 1000 RPM) to deceive the system. For vehicle speed, the bytes D4 and D5 are used, and attackers can modify these values to simulate different speeds, like 0x64 for 100 km/h or 0x32 for 50 km/h. Additionally, the gas pedal position is stored in D6 and D7. Altering these bytes can make the system believe that the gas pedal is fully pressed, like changing the value to 0x40 0x9C, simulating full acceleration. By modifying these bytes, the attacker injects false data that can mislead the vehicle's control system, causing it to make dangerous or erroneous decisions, such as improper steering, incorrect speed adjustments, or faulty acceleration responses.

Table 3. CAN Message IDs and Data for IoV Vehicle Parameters

CAN ID	D0	D1	D2	D3	D4	D5	D6	D7	Comments
0x80	SWH	SWL							**SteeringPositionSensor** SW - steering wheel position in 0.1 degrees (90 degrees = 900)
0x201	RPMH	RPML							RPM - engine RPM multiplied by 4 (4000=1000RPM)
0x201					SPEED				SPEED - divided by 2 (50 =100km/h)
0x201							GASH	GASL	GAS - gas pedal position (range 0-0xc800)
0x440	AC?								**AC control module** AC? = 0x80 when AC is on (bit 7 - AC state)
0x430							HB?		HB? = 0x20 when hand brake is on (bit 5 - hand brake state)

Dataset and Pre-processing

In this study, the CICIoV2024 dataset is used, which was sourced from the IoV dataset, includes Benign, DDoS, and Spoofing attacks. Figure 5 illustrates the preprocessing operations involved in preparing the CICIoV2024 dataset, which is derived from a 2019 Ford Mondeo via the OBD-II interface. Initially, the raw data includes 1,408,219 entries with 9 features in hexadecimal format (ranging from 00 to FF) and labeled for five different types of attacks. This raw dataset (See Table 4) undergoes a conversion process to produce two additional formats: one with the same 9 features represented in decimal format (0–255), and another expanded version with 153 features in binary format (0 or 1).

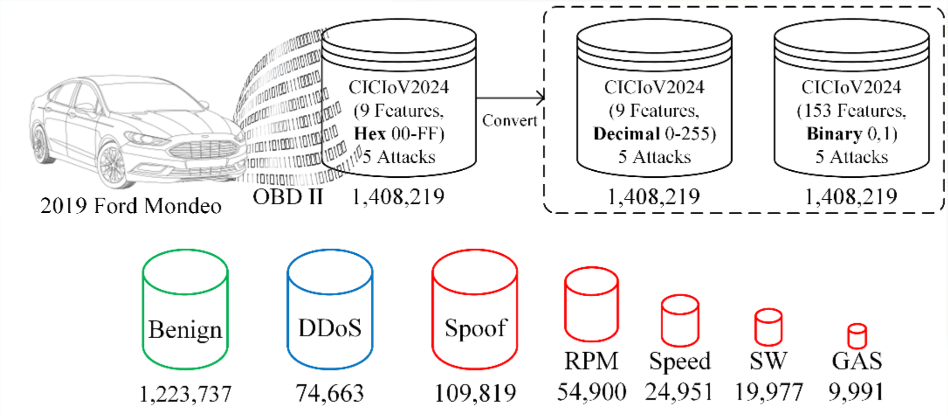

Figure 5. Preprocessing Operations on CICIoV2024 Dataset.

The dataset contains both benign and malicious samples, with benign data making up the majority (1,223,737 entries), while various attack types such as DDoS (74,663), Spoof (109,819), RPM (54,900), Speed (24,951), Steering Wheel (19,977), and GAS (9,991) represent different intrusions targeting vehicular systems. This preprocessing ensures the data is structured for diverse machine learning tasks and analysis across multiple feature representations. Binary Description of CICIoV2024 dataset is presented in Table 5.

Table 4. CICIoV2024 Dataset Distribution: Attack Categories and Counts

Class	**Category**	**Attack**	**Count**
Benign (1,222,737)	Benign	-	1,223,737
Attack (184,482)	DoS (74,663)	DoS	74,663
	Spoofing (109,819)	GAS	9,991
		Steering Wheel	19,977
		Speed	24,951
		RPM	54,900

Table 5. CICIoV2024 Binary Dataset Description

	Mean	std	min	25%	50%	75%	max
ID	537,2079	322,48	65	357	516	578	1,438
DATA_0	71,0866	88,97717	0	0	16	127	255
DATA_1	69,98925	95,58374	0	0	12	128	255
DATA_2	55,01127	72,76584	0	0	13	125	255
DATA_3	57,45364	90,32077	0	0	0	92	255
DATA_4	45,28517	64,45835	0	0	6	86	255
DATA_5	53,88261	94,33612	0	0	0	63	255
DATA_6	71,74914	101,6872	0	0	0	138	255
DATA_7	60,27477	99,96547	0	0	0	80	255

Figure 6 displays the distribution of categories in the CICIoV2024 Dataset using a pie chart. The chart highlights a significant imbalance among the data categories. The majority of the data is labeled as BENIGN, comprising 86.9% of the total entries. In contrast, the SPOOFING category accounts for 7.9%, and DDoS represents only 5.3% of the dataset. This uneven distribution emphasizes the dominance of normal traffic in the dataset, which poses challenges for training machine learning models, particularly in detecting less frequent but critical attack types such as DDoS and Spoofing. Addressing this imbalance is crucial for developing robust intrusion detection systems for in-vehicle networks.

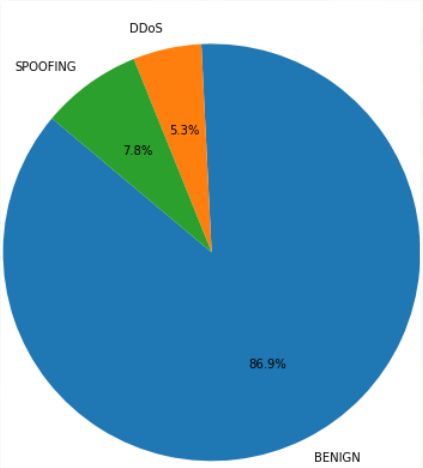

Figure 6. Distribution of Categories in CICIoV2024 Dataset.

Figure 7 provides a detailed bar chart representation of the attack count percentages in the CICIoV2024 Dataset. As illustrated, Benign traffic dominates the dataset, comprising 86.90% of all records, reinforcing the heavy class imbalance seen previously. Among the attack types, DDoS attacks account for 5.30%, followed by RPM spoofing at 3.90%, Speed spoofing at 1.77%, Steering Wheel spoofing at 1.42%, and GAS spoofing at 0.71%. This detailed breakdown shows that while benign data heavily outweighs malicious samples, a variety of spoofing attacks are present in smaller proportions.

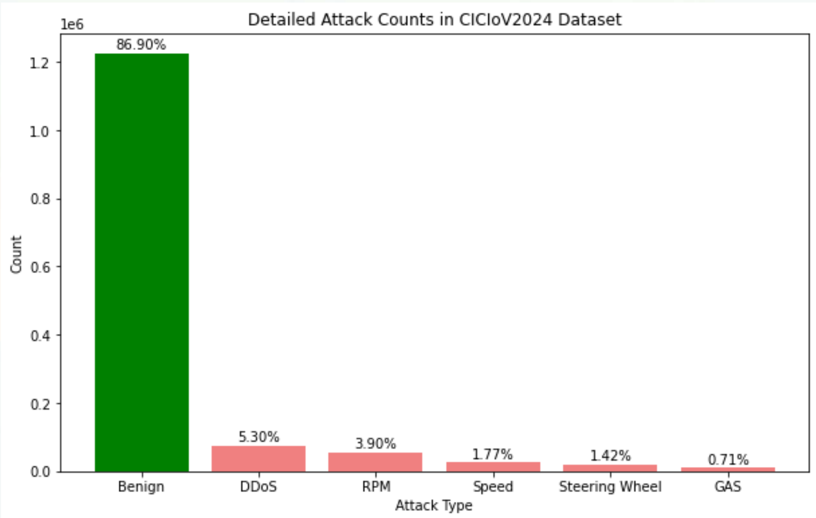

Figure 7. Detailed Attack Counts Percentages in CICIoV2024 Dataset.

Model Training and Evaluation

The model training and evaluation processes were conducted using the CiCIoV2024 dataset, focusing on a total of eight machine learning algorithms: RT, RF, LR, MLP, NB, XGBoost, J48, and AdaBoost. The dataset was split into 80% for training and 20% for testing, and a 10-fold cross-validation approach was employed to ensure reliable and consistent performance results across different data partitions.

All models were implemented using Weka version 3.9.6 [9], and their hyperparameters were carefully tuned for optimal performance. Table 6 provides a detailed overview of the model configurations used in Weka.

TABLE 6. Machine Learning Model Configurations in Weka

Model	Parameters
Adaboost	weka.classifiers.meta.AdaBoostM1 -P 100 -S 1 -I 10 -W
J48	weka.classifiers.trees.J48 -C 0.25 -M 2
LR	-R 1.0E-8: Ridge regularization parameter -M -1: Maximum number of iterations -S 1: Random seed
MLP	-L 0.3: Learning rate = 0.3 -M 0.2: Momentum = 0.2 -N 500: Number of epochs = 500 -V 0: No validation set used -S 1: Random seed
NB	-K: Use kernel estimator -D: Use supervised discretization
RF	-I 100: Number of trees = 100 -K 0: Use square root of the number of features -S 1: Random seed -num-slots 1: Use 1 thread
RT	-K 0: Select all features -S 1: Random seed -minNum 1: Minimum number of instances per leaf
XGBoost	-numBoostRound 100: Number of boosting iterations -learningRate 0.3: Learning rate -maxDepth 6: Maximum depth of the trees -subsample 0.8: Subsampling ratio

Once the data preprocessing and feature selection steps were completed, all models were trained on the training subset. Among them, XGBoost was of particular interest due to its proven efficiency in handling high-dimensional and imbalanced datasets, typical in DDoS detection scenarios. The XGBoost model was optimized using the binary logistic loss function, with parameter updates performed using gradient descent over multiple iterations.

The model performance was assessed using the held-out 20% test set, and evaluated based on several critical metrics: accuracy, precision, recall, F1 score, and the confusion matrix. Accuracy measured the overall correctness of predictions, while precision and recall highlighted the model's ability to correctly detect attack traffic. The F1 score, as the harmonic mean of precision and recall, offered a balanced view of classifier performance, especially valuable in security-related applications where both false positives and false negatives can have significant consequences [10].

Experimental Results

This section presents the experimental results obtained using various machine learning algorithms for detecting DDoS attacks in the CiCIoV2024 dataset. The evaluation was carried out in two modes: an 80/20 percentage split and 10-fold cross-validation. To assess the effectiveness and robustness of each model, several key performance metrics were considered, including accuracy, true positive rate (recall), false positive rate (FPR), precision, F-measure, and mean absolute error (MAE).

A. Model Accuracy

Table 7 summarizes the binary classification performance of eight machine learning models: AdaBoost, J48, Logistic Regression, MLP, Naive Bayes, Random Forest, Random Tree, and XGBoost. The results indicate that tree-based ensemble methods, particularly XGBoost, Random Forest, Random Tree, MLP, and J48, achieved near-perfect performance, with accuracy, recall, precision, and F1-scores all reaching 1.000 in most test modes. Notably, XGBoost produced the highest performance overall, reaching 99.9999% accuracy with zero error (MAE = 0.0000) in both evaluation settings.

Test Mode	Algorithms	ACC %	TPR (Recall)	FPR	Precision	F-Measure	MAE
Percentage Split (80%)	Adaboost	98.9352	0,989	0,070	0,989	0,989	0.0956
	J48	99.9993	1,000	0,000	1,000	1,000	0.0000
	Logistic Regression	87.2648	0,873	0,823	0,854	0,822	0.1831
	MLP	99.9957	1,000	0,000	1,000	1,000	0.0002
	Naive Bayes	67.7582	0,678	0,163	0,878	0,730	0.3108
	Random Forest	99.9993	1,000	0.000	1,000	1,000	0.0027
	Random Tree	99.9993	1,000	0,000	1,000	1,000	0.0027
	XG-Boost	99.9999	1,000	0,000	1,000	1,000	0.0000
K-Fold 10	Adaboost	98.935	0,989	0,071	0,989	0,989	0.0955
	J48	99.9987	1,000	0,000	1,000	1,000	0.0036
	Logistic Regression	87.3268	0,873	0,822	0,854	0,823	0.1825
	MLP	99.9794	1,000	0,000	1,000	1,000	0.0003
	Naive Bayes	67.8273	0,678	0,163	0,878	0,731	0.3104
	Random Forest	99.9987	1,000	0,000	1,000	1,000	0.0000
	Random Tree	99.9987	1,000	0,000	1,000	1,000	0.0000
	XG-Boost	99.9999	1,000	0,000	1,000	1,000	0.0000

Conversely, Naive Bayes and Logistic Regression models underperformed compared to the other classifiers. Naive Bayes recorded the lowest accuracy (67.8%) and the highest error values, indicating its limitations in modeling the complex patterns inherent in DDoS traffic. Logistic Regression showed moderate performance, with an accuracy around 87.3%, but suffered from higher false positive rates (above 82%) in both evaluation settings.

These results clearly demonstrate the superiority of ensemble learning methods (e.g., XGBoost, AdaBoost, Random Forest) and deep learning-based MLP models in accurately distinguishing between benign and attack traffic in the CiCIoV2024 dataset. Their low error rates and perfect classification metrics emphasize their suitability for deployment in real-time intrusion detection systems within IoT-based network environments.

B. Confusion Matrix

The confusion matrix in Figure 8 presents the performance of the XGBoost classifier using the 80/20 percentage split on the CiCIoV2024 dataset. This visual representation provides clear insight into the model's classification accuracy for both benign and attack traffic.

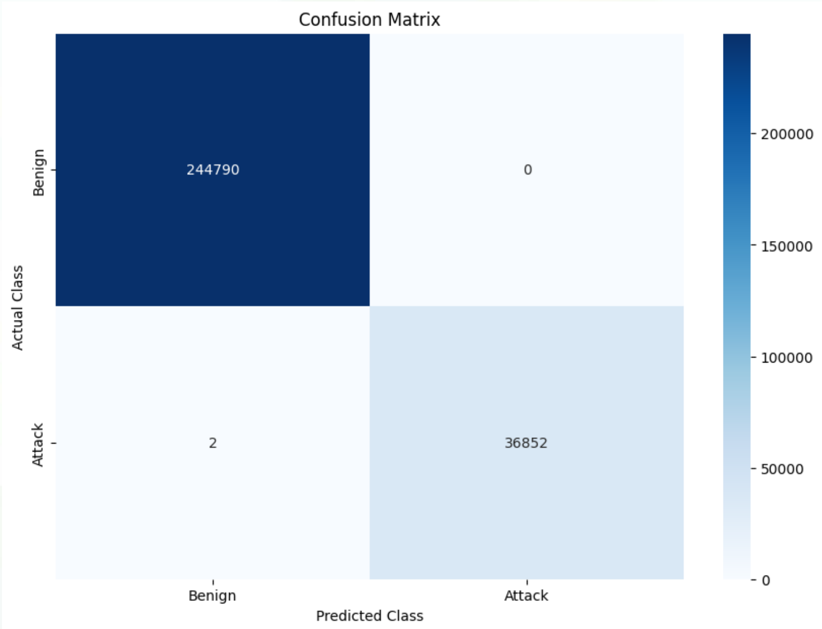

Figure 8. Confusion Matrix for XGBoost Percentage Split 80%.

As shown, the XGBoost model demonstrates near-perfect classification performance. It correctly classified 244,790 benign instances and 36,852 attack instances, with zero false positives and only 2 false negatives. This results in a true positive rate (recall) of approximately 0.9999, and precision and F1-score values of 1.000, as reported in Table VII. The absence of false positives highlights the model's reliability in preventing unnecessary alerts for normal traffic, while the minimal false negatives suggest only a negligible number of attack instances went undetected.

Overall, this confusion matrix confirms XGBoost's high accuracy and robustness, reinforcing its effectiveness as a leading candidate for real-time DDoS detection in IoT environments.

A. SHAP Analysis

Figure 9 displays a SHAP beeswarm plot that illustrates the distribution of SHAP values for each feature, highlighting their contribution to the model's predictions across the dataset. The plot effectively reveals both the magnitude and direction of each feature's impact. Features such as 'DATA_1', 'DATA_3', and 'DATA_5' exhibit a wide spread of SHAP values, indicating their strong influence on the model output. Notably, higher values of 'DATA_1' and 'DATA_3' (shown in red) are associated with a negative impact on predictions, as evidenced by their concentration on the left side of the plot. In contrast, some features like 'DATA_0' and 'DATA_6' display red points predominantly on the right, suggesting that higher values of these features contribute positively to the model's output. This visualization enhances interpretability by showing how both high and low feature values influence individual predictions.

Figure 9. SHAP Beeswarm Plot

Figure 10 presents SHAP waterfall plots for individual predictions, illustrating how each feature contributes to the final model output. The plots start from the model's expected output (base value), and each bar represents the additive effect of a feature—pushing the prediction either upward (positive, in red) or downward (negative, in blue). In the left plot, the largest negative impact comes from DATA_1, followed by DATA_0 and DATA_6, while DATA_7 has the most notable positive contribution. Similarly, the right plot highlights DATA_1 as the dominant negative contributor, significantly lowering the prediction value, while DATA_7 and DATA_5 provide positive contributions. These visualizations effectively explain how specific feature values drive individual prediction outcomes and help identify which features most influence the model's decision for a particular instance.

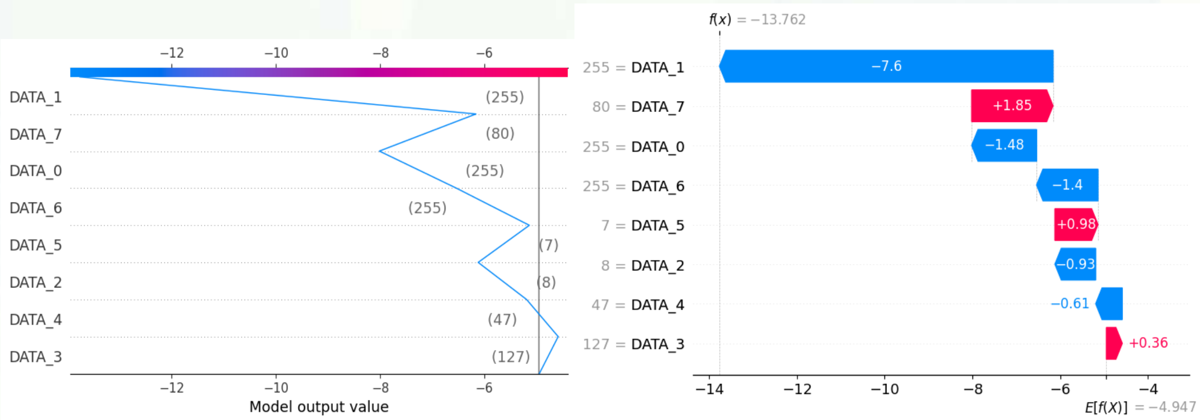

Figure 10. SHAP Waterfall Diagrams

Discussion

The integration of XAI techniques with machine learning models for cybersecurity in IoT environments offers a promising avenue to enhance the detection and interpretation of DDoS attacks. This study's analysis provides insights into how specific input features influence model decisions, enabling a deeper understanding of anomalous network behaviors.

The SHAP analysis, visualized in Figures 9 and 10, highlights the differential contributions of features to the model's output, emphasizing the critical role of interpretability in understanding complex model decisions. The SHAP beeswarm plot (Figure 9) shows that features such as DATA_1, DATA_3, and DATA_5 exhibit high variability and strong influence on predictions. Notably, high values of DATA_1 and DATA_3 tend to suppress the model output, as evidenced by their negative SHAP values, which are clustered on the left. In contrast, features like DATA_0 and DATA_6 sometimes contribute positively, depending on the instance-specific context.

Further supporting these findings, the SHAP waterfall plots (Figure 10) illustrate the decomposition of individual predictions, showing how each feature incrementally shifts the prediction from the model's base value to the final output. For instance, in both example cases, DATA_1 consistently exerts a strong negative impact, while features such as DATA_7 and DATA_5 contribute positively. These detailed explanations help reveal not only which features are influential but also how they influence individual predictions a crucial requirement in high-stakes domains such as cybersecurity.

These insights carry significant implications for the design of AI-driven defense systems. As AI increasingly assumes decision-making responsibilities in critical infrastructures, the demand for transparency becomes a practical necessity rather than a theoretical concern [19]. By offering clear, instance-level justifications for model decisions, XAI methods like SHAP improve stakeholder trust and facilitate more informed management of AI systems, reducing the risks of false positives and false negatives—key challenges in cybersecurity settings [21].

Moreover, the study opens promising directions for future work, particularly in deploying interpretable models in real-time intrusion detection systems. Extending SHAP-based interpretability into live environments may enhance the responsiveness and reliability of DDoS defense mechanisms, in line with the forward-looking perspective of [22] on XAI's evolving role.

Ultimately, incorporating XAI principles into machine learning workflows not only enhances detection capabilities but also ensures that the decision-making process remains transparent and trustworthy. This study underscores the urgent need for continued research in explainable machine learning to keep pace with the rapidly evolving landscape of cyber threats.

Conclusion

In conclusion, this paper emphasizes the significant role of Explainable AI (XAI), particularly SHAP, in improving the detection of DoS and four types of spoofing attacks within IoV systems. By utilizing the CICIoV2024 dataset, we have demonstrated how SHAP can effectively identify the most impactful features responsible for detecting these attacks and assessing their severity. The dataset includes DoS attacks and spoofing variants such as Steering Wheel, RPM, Gas, and Speed, providing a comprehensive foundation for analyzing IoV security threats. The results show that XAI methods enhance the transparency of machine learning models and also offer valuable insights into the key factors driving attack detection. To achieve the best results, eight machine learning algorithms were used, highlighting the importance of selecting the most effective models for attack detection. This work lays a solid foundation for further research in IoV cybersecurity and the application of XAI for transparent and effective defense mechanisms. The study serves as the beginning of efforts to explore and optimize IoV security solutions, with the goal of enhancing protection against cyber threats. In the future, we plan to explore additional techniques and datasets to refine detection systems and develop better protection mechanisms for IoVs.

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