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RESIDENTS' QUALITY OF LIFE IN THE CONTEXT OF SMART CITIES

Institute of Sustainability

Supervisor:

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1. Research background and justification of the topic

1.1. Conceptual underpinnings, theoretical background and justification of the topic

Recent researchers indicate a significant paradigm shift from infrastructure-centric approaches toward citizen-oriented quality of life and sustainability frameworks (Myeong et al., 2022). The centrality of quality of life in smart city research is emphasized by Csukas and Szabó (2022) who state that "improving the quality of life of citizens is a central concept, and we assume it to be an ultimate goal of SC developments" (p. 3). Szarek-Iwaniuk and Senetra (2020) describe smart cities as being "characterized by sustainable economic development and a high quality of life, which are driven by investments in human and social capital, traditional (transport) and modern (ICT) infrastructure, responsible resource management, and social participation" (p. 4). This perspective is reinforced by Vidiasova and Cronemberger (2020) who note that "enhancing citizens' quality of life and experience with city services is often regarded as the ultimate goal for smart city initiatives" (p. 3). The evolution of smart city conceptualization is reflected in emerging terminologies: "human smart cities" (Keshavarzi et al., 2021), "citizen-centric smart cities" (Shami et al., 2022), "people-centric smart cities" (Ji et al., 2021), "happiness driven smart cities" (Zhu et al., 2022), and "smart age-friendly cities" (Barletta et al., 2020; Li and Woolrych, 2021). A smart city comprises policies and programs aimed at enhancing municipal service efficiency and effectiveness, promoting urban (re)development, enabling private investment, and improving quality of life through information and communication technologies investment (Edge et al., 2020). ICT can be utilized to achieve improved quality of life in liveable and secure environments (Cantuarias-Villessuzanne et al., 2021).

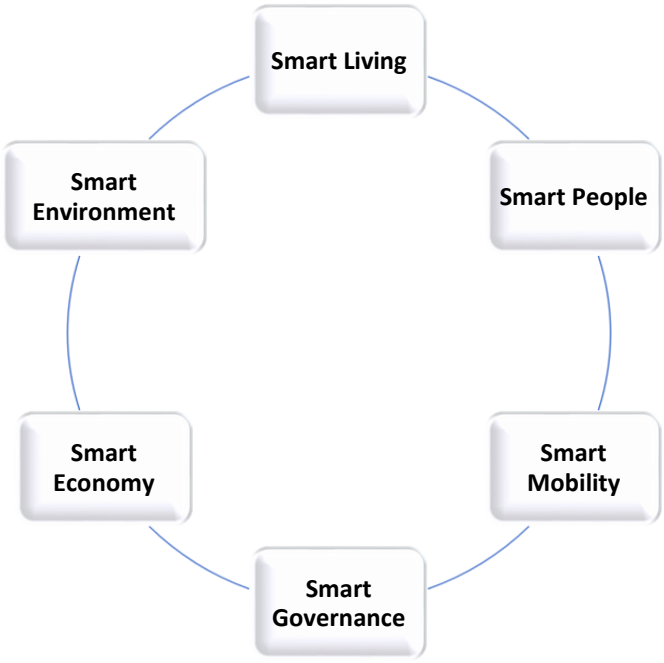
Smart living has been identified as the most crucial domains of a smart and sustainable city (Ozkaya and Erdin, 2020) and is frequently equated with quality of life (Giffinger et al., 2010; Braga et al., 2021; Valencia-Arias et al., 2021; Shami et al., 2022). Ozkaya and Erdin (2020) suggest that smart living includes healthcare conditions, education facilities, individual safety, housing quality and affordability, cultural interaction opportunities (e.g. events, heritage sites, museums, shopping), tourist attractivity, and social cohesion (e.g. homelessness, volunteering). Within this framework, technology is positioned as a means to improve citizens' lives rather than representing a goal in itself (Edge et al., 2020; Cantuarias-Villessuzanne et al., 2021; Shami et al., 2022).

However, clear domain differentiation remains difficult due to the multifaceted nature of influences on smart living. Smart city domains demonstrate significant interconnectivity: governance systems and economic frameworks share regulatory boundaries; mobility networks and environmental outcomes are intrinsically linked; and human capital development directly affects quality of life measures. Such interdependencies demand integrated, holistic management strategies rather than compartmentalized approaches to urban innovation. For this reason, although the research emphasised smart living because of its close connection to quality of life, it was considered important to include other dimensions of smart cities such as economic factors (e.g. cost of living, job opportunities) and infrastructure (e.g. transport and environment).

As yet, only a few articles have been devoted to the topic of AI or artificial intelligence for improving the quality of life in smart cities. It is documented that AI is most used in the areas of transportation, environmental management, healthcare, cyber-security and communication (Ullah, Quddusi & Haider, 2024). AI can be useful especially in mobility planning, energy management and healthcare data handling (Szpilko et al., 2023). Although there is consensus in the literature that AI can improve quality of life in urban areas, it also brings new challenges, especially relating to data security, privacy, and regulatory compliance (Szpilko et al., 2023).

This Thesis examines the role of quality of life within smart city frameworks from a citizens' perspective. The primary objective of this Dissertation is to develop a comprehensive Smart City Quality of Life (SCQOL) indicator system that positions citizens at the centre of Smart City (SC) development, while formulating evidence-based recommendations for enhancing residents' quality of life (QoL). This includes providing municipalities and urban planners with a robust analytical framework for evaluating and optimizing inhabitants' QoL through systematic implementation strategies using a community-orientated "bottom-up" approach. As presented in Figure 1, Giffinger and Gudrun (2010) identified six dimensions of SC in previous literature: smart economy, smart mobility, smart environment, smart people, smart governance, and smart living. These domains have been adopted in multiple subsequent studies by researchers, often with some modifications or expansions (Ortega-Fernández et al., 2020; Ozkaya and Erdin, 2020; Bielińska-Dusza et al., 2021; Braga et al., 2021).

Figure 1 Main domains of a smart city (Giffinger, 2010)



This Thesis builds up on a systematic literature review that analyses definitions and concepts of smart city and quality of life, as well as the domains and indicators used to measure QoL. The study includes the design of a resident-based questionnaire that refines and expands on these SCQOL indicators. The investigation is based on an in-depth examination of Budapest as a contextual case study, offering practical insights for future smart city development initiatives that improve resident quality of life.

The main research aim is hence to ***define and measure the most important elements of quality of life for residents in a smart city***.

1.2. Contextual focus

The absence of data documenting citizens' needs in smart cities was highlighted in previous quality of life research (Csukás and Szabó, 2018; Csukás and Szabó, 2022). This gap prompted the researchers to conduct a resident-centred study of quality of life in Budapest as an emerging smart city. Smart developments in Budapest have been progressing for over a decade (Csukás and Szabó, 2021). However, initial assessments indicated that Budapest was falling behind regional

competitors (Csécsei, 2020), particularly regarding quality-of-life indicators such as healthcare, housing, air pollution, and interpersonal trust (European Commission, 2023). Previous research identified that issues like gentrification, land use conflicts, and excessive tourism have led to what is termed "disrupted wellbeing" (Namaz and Tvergyák, 2023:1). In the past, like other Central and Eastern European cities, Budapest prioritized economic development over environmental and social considerations (Vesalon and Creţan, 2019). The recent situation showed improvement, with the Economist Intelligence Unit (EIU, 2024) ranking Budapest as "the most liveable city in Eastern Europe" and 32nd globally among "world's most liveable cities". According to 2023 data, the perceived level of citizen participation in municipal decision-making rose from 32.3 points in 2019 to 34 points in 2023 (BVK, 2025). Additionally, Budapest achieved recognition as the 4th "Most Liveable Student City" in 2024 (The Campus Advisor, 2024). However, a 2025 analysis also found that satisfaction with key indicators such as healthcare services, green space availability and public transport was ranked considerably below other European capitals (Növekedés.hu, 2025).

In 2017, Budapest established its Smart Budapest Vision, structured around seven strategic pillars encompassing economic development and employment generation, sustainable energy initiatives, transport infrastructure enhancement, green space optimization, historical urban preservation and renewal, social regeneration, and tourism development. Since adopting its smart-city strategy, the city has launched sensor-networks, mobility plans, and digital service initiatives aimed at enhancing walkability, connectivity and liveability. The national smart-city market in Hungary is growing, with the smart-cities segment projected to reach about US$116.5 million in 2025, with nearly 10 % annual growth to 2029—indicating increased investment that could support Budapest’s agenda (Statista, 2025). However, on the global ranking front, Budapest dropped to 89th in the International Institute for Management Development (IMD) Smart Cities Index in 2024, attributed to weaknesses in affordable housing, health services and security (Pénzcentrum.hu, 2024).

The research in this Thesis diverges from previous studies (e.g. Fekete, 2023) by concentrating on social aspects and quality of life issues, including attitudes toward smart technology adoption. Fekete's (2023) research revealed that only 40% of residents understood the concept of 'smart city', with even fewer able to identify specific smart solutions. However, the 2022 Census (HCSO, 2022) indicates high digital engagement, with 83% of citizens participating in digital activities.

The city's administrative structure consists of 23 districts as shown, each with distinct economic, social, and cultural characteristics. The autonomous nature of these districts presents challenges for unified city management, often resulting in conflicts over development priorities, regulations, and resource allocation. For example, this can have implications for tourism management where several attractions span more than one district. This is especially true of central areas such as the so-called 'party quarter' mainly located in districts VI and VII, which have the highest concentration of tourists and Airbnb units (Pérez Garrido et al., 2022). This has led to complaints from local residents about overtourism or touristification and related impacts and behaviour (Smith et al., 2019).

It is difficult to differentiate between the concepts of gentrification, touristification and overtourism, especially in a city like Budapest where most of the impacts of tourism are concentrated in a limited number of central districts. In the past, many tourists were attracted by the cultural and heritage sites around Andrássy Avenue and the World Heritage Site, including the castle district. In recent years, the 'party quarter' spanning the former Jewish ghetto districts VI and VII gained popularity. More recent developments try to encourage tourists (including cruise passengers) to visit the City Park and its new cultural attractions (Smith & Chang, 2025). In accordance with the definitions of Santos-Izquierdo et al. (2025), it could be said that touristification (defined as the transformation of urban spaces into 'tourist places') has occurred in the city's former Jewish ghetto area, now a night-life hub and 'party quarter'. Overtourism is common in this area because of overcrowding and the pressure on infrastructure. Subsequent gentrification and displacement of locals have taken place because of rising house prices and cost of services, coupled with the negative impacts of tourism.

Regulations vary across districts in Budapest, for instance regarding closing hours of bars. This study also includes tourism as an element of smart living, as it has been suggested that smart tools could help to manage tourism better, as well as other quality of life-related services like transport, traffic, parking, attraction capacity, even housing (Pérez Garrido et al., 2022).

1.3. Research gaps and contextual tensions

Compared to previous studies, this study's timeliness and relevance for Budapest and Hungary are evidenced through multiple aspects. The research addresses Budapest's relatively low rankings in

European Quality of Life indices and responds to a notable lack of empirical data regarding residents' needs and demands. By providing empirical research focused on residents' perspectives, this study helps bridge a significant knowledge gap in Budapest's smart city development trajectory.

A major gap can exist between planning and the measurable impact of digital interventions, especially in the domain of data-driven monitoring and governance (Hsu, Schletz & Yu, 2023). It should also be noted that Budapest's urban governance currently confronts various barriers and restrictions stemming from political cooperation deficiencies, economic constraints, and funding limitations. However, this Dissertation does not aim to investigate the processes behind or barriers to smart city initiative implementation; rather, it focuses on examining how residents perceive existing and ongoing developments.

1.4. Research aims and questions

The primary aim of this Thesis is:

To define and measure the most important elements of quality of life for residents in a smart city

The main aim of the Thesis and publications filled the following gaps which built on previous relevant studies:

- *To supplement the lack of citizen-focused research in smart cities (Myeong et al., 2022)*
- *To address the need to be responsive to communities and improve people's quality of life (Del-Real et al., 2023; Wang and Zhou, 2023).*
- *To assess the role of tourism in smart cities and especially smart living (Ji et al. (2021)*
- *To measure how far technology can be used as a means to improve citizens' lives in smart cities (Cantuarias-Villessuzanne et al., 2021; Shami et al., 2022).*
- *To collect data documenting citizens' quality of life in smart cities that was missing in previous research in Budapest (Csukás and Szabó, 2018; Csukás and Szabó, 2022)*
- *To provide evidence for goverbnmental policies and practice (Nunes et al. 2021; Chen and Chan 2023), and to make recommendations for urban planners, managers and municipality.*

The research questions were then designed based on these gaps:

RQ1. How can quality of life be defined and conceptualised in the context of a smart city?
RQ2. How can residents' quality of life be measured in a smart city?
RQ3. What are residents' attitudes to smart city developments and smart tools in Budapest?
RQ4. What is the relationship between tourism and quality of life in Budapest and how can smart tools assist in the management of tourism?
RQ5. What are the implications for smart city planning and management to improve residents' quality of life?

These research questions were addressed through a systematic literature review, the design of a questionnaire for local residents in context (Budapest), data analysis, and recommendations for smart city management.

2. The methods used

2.1. The overview of research design

To provide a structured overview of the empirical design, the following Figure 2 and Table 1 summarize the core elements of five phrases of the study. The research employed a trilingual questionnaire presented in Table 1 (English, Hungarian and Mandarin Chinese) to accommodate Budapest's diverse population of resident consumers. The data collection yielded 453 valid responses. Distribution occurred through both electronic platforms (web-based interfaces, QR codes, District Forums, expatriate networks) and paper-based instruments, which were filled in by interviewers in different districts of the city.

Figure 2. illustrates the comprehensive process of research and statistical analysis.

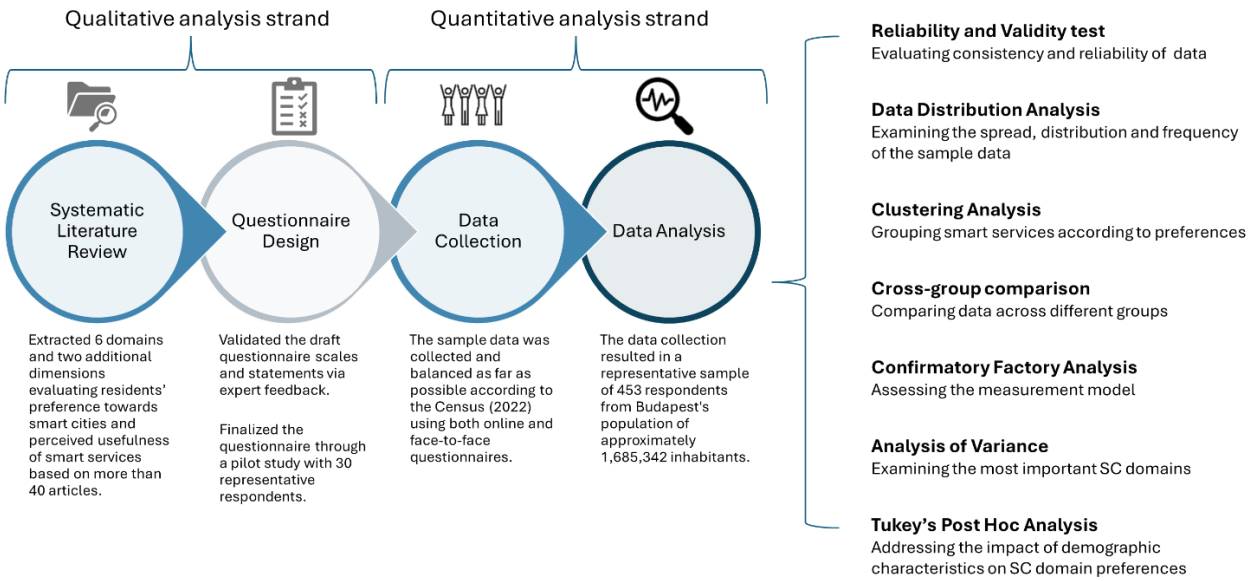


Table 1. Domains, indicators and statements chosen to measure SCQoL based on previous studies

Domain of smart cities	**Indicators**
Smart economy (Ivaldi et al., 2020; Ortega-Fernández et al., 2020, Ozkaya and Erdin, 2020; Braga et al., 2021; Kim et al., 2021;Pira, 2021; Valencia-Arias et al., 2021; Vidiesova and Cronemberger, 2021; Zhu et al., 2022; Chen and Chan, 2023)	Cost of living Jobs
Smart governance (Ozkaya and Erdin, 2020; Braga et al., 2021; Mills et al., 2022; Zhu et al., 2022; Chen and Chan, 2023; Leung and Lee, 2023)	Information provision Consultation Complaints
Smart mobility (Oh, 2020; Ortega-Fernandez et al., 2020;	Public transport Parking

Ozkaya and Erdin, 2020; Kim et al., 2021; Keshavarzi et al., 2021; Nunes et al., 2021; Valencia-Arias et al., 2021; Chen and Chan, 2023)	Cycling Traffic
Smart environment (Liu et al., 2020; Oh, 2020; Shami et al., 2022; Zhu et al., 2022)	Air quality Green spaces Cleanliness Noise levels Sustainability
Smart people (Cornejo Ortega and Malcolm, 2020; Ozkaya and Erdin, 2020; Bielińska-Dusza et al., 2021; Del-Real et al., 2023; Csukás and Szabó, 2021; Cantuarias-Villessuzanne et al., 2021; Ligarsky and Wolny, 2021; Pira, 2021; Shami et al., 2022; Chen and Chan, 2023)	Education Social issues Image Atmosphere

Smart living (Oh, 2020; Ortega and Malcolm, 2020; Ozkaya and Erdin, 2020; Bielińska-Dusza et al., 2021; Cantuarias-Villessuzanne et al., 2021; Csukás and Szabó, 2021; Ji et al, 2021; Ligarsky and Wolny, 2021; Pira, 2021; Shami et al., 2022)	Housing Healthcare Safety Leisure Culture Tourism

2.2. Research phases

The research was conducted in several stages as depicted in previous Figure 1 and was summarised in Table 2 as follows. The final questionnaire sample included 453 validated responses. Hungarian 2022 Census data (HCSO, 2022) was meticulously examined and aligned as far as possible by utilizing a representative quota sampling method. A chi-square test of independence was performed comparing the sample with Budapest's overall population. The analysis utilized a multi-tool approach, employing Power BI for primary analysis and interactive visualizations, while data preprocessing and analysis were conducted through Microsoft Excel, Python and Rstudio.

Table 2. Summary of the methodology

Phase I. Systematic review of smart city and quality of life literature
The initial phase commenced with a comprehensive literature review conducted through the Web of Science database focusing on the key words 'smart cities' and 'quality of life'. 38 of the most relevant and recent were analysed in depth
Phase II. Development of SCQOL domains and indicators

The measurement instrument employed closed-ended items with standardized Likert scaling, consistent with established smart city and quality of life assessment protocols (e.g., Bielinska-Dusza et al., 2021; Chen & Chan, 2023; Ji et al., 2021; Oh, 2020; Shami et al., 2022; Vidiasova & Cronemberger, 2020). Smart tools for each domain were identified through previous research and AI-generated suggestions.
Phase III. Pilot test
30 interviewees were selected from the target demographic groups and the draft questionnaire was sent to them. Native-speaking experts in social research reviewed the draft questionnaire for language accuracy and design effectiveness. The feedback obtained during this phase was instrumental in refining the research instrument for optimal effectiveness. Based on pilot feedback, several questions were refined, particularly regarding housing affordability and education levels.
Phase IV. Questionnaire distribution
The questionnaire was initially distributed through online platforms such as district resident forums, ex-patriate networks and by snowball sampling. Then the sample was balanced as far as possible according to the Census (2022) using face-to-face questionnaires distributed in central locations targeting-represented groups (e.g. men, older residents, those from suburban districts). The data collection consequently resulted in a representative sample of 453 respondents from Budapest's population of approximately 1,685,342 inhabitants.
Phase V. Analysis and findings
This phase involved data analysis of the questionnaire findings using appropriate statistical methods in order to identify significant patterns and trends, and to assess demographic variations in response. The dataset was prepared in Power BI and Microsoft Excel, the statistical analysis and visualisation were conducted using programming languages Python and R. A set of statistical and mathematical analyses were conducted. First of all, the researchers evaluated the reliability and validity of

collected data and key indicators which were calculated including Kaiser–Meyer–Olkin (KMO), Average Variance Extract (AVE), Composite Reliability (CR). This was followed by examining the spread, distribution and frequency of the data. Cluster analysis further provided a deeper understanding by grouping smart services according to priority. Based on previous theoretical foundations, the measurement model was examined via confirmatory factory analysis. Analysis of variance identified the most important dimensions in SC. Tukey's post hoc analysis addressed the influence brought by different socio-demographic characteristics.
Phrase VI Discussion and Conclusion
The findings were disseminated through International and National conferences, reviewed by experts from the relevant areas. They were then well-structured and published in reputable international journals. The primary publications have been enumerated in Chapter 5 of this Booklet.

3. Scientific results of the Dissertation (in bullet points)

The Thesis advances several novel theoretical and empirical findings, summarized below as the key scientific results of the Thesis.

- Our Systematic Literature Review demonstrates the central importance of quality of life to smart cities. Investigations into the significant dimensions and measures of SCQoL can assist urban developers in prioritizing and investing in smart services which meet residents' needs. There is still a discrepancy between residents' needs and policies.
- We identified six domains of smart cities and subdomains, a reliable and valid measurement was created including smart economy (related to cost of living, jobs), smart mobility (related to public transport, parking, cycling and traffic), smart environment (covering air quality, green spaces, cleanliness, noise levels and sustainability), smart governance (related to information provision, consultation, complaints), smart people (education, social issues, image, atmosphere). The main domains of smart living and their relevant indicators

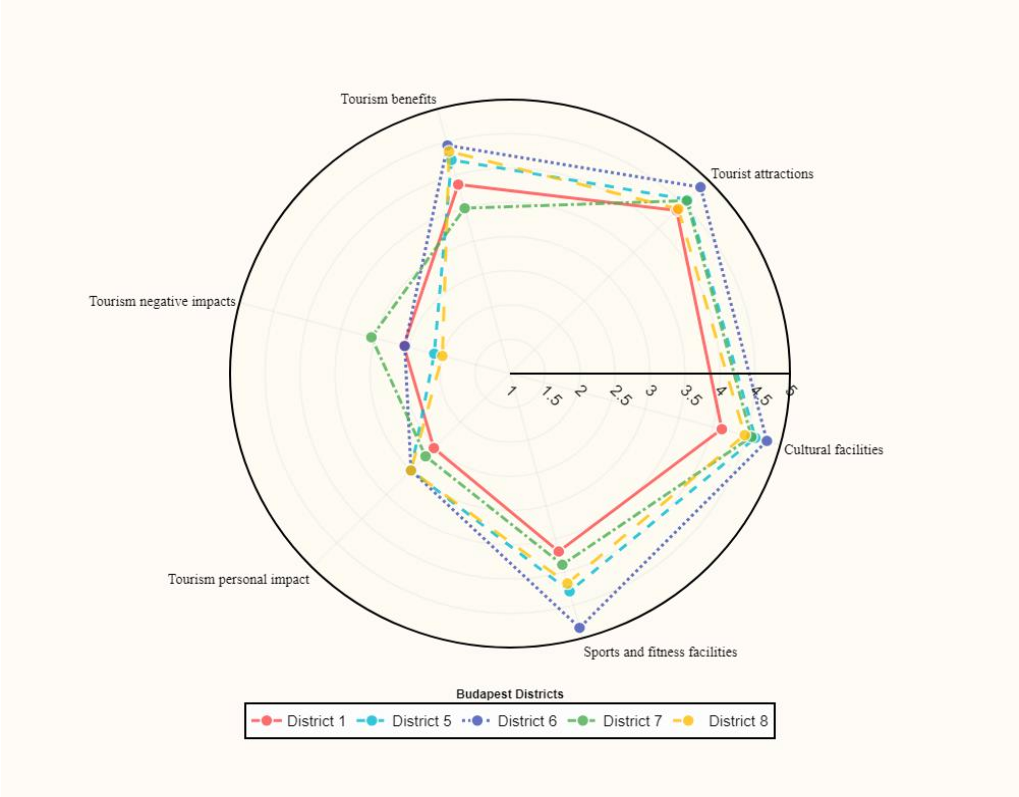
include housing, health, safety, education, environment, social cohesion, leisure, culture and tourism. This research synthesized a valid measurement instrument based on six established domains of SC.

- Smart Living emerged as the most valued domain, followed by Smart People and Smart Mobility, while Smart Economy and Smart Governance ranked lowest. Although governance is central to strategic smart city management, it often remains invisible to residents.
- Citizens exhibit heightened positive attitudes and increased support for smart city initiatives when they perceive direct benefits to their lifestyle, local economic growth and infrastructure enhancement,
- The domains of quality of life (QoL) most closely related to tourism, namely transport, leisure, culture, atmosphere and the positive benefits of tourism, were given higher ratings than any others. In the districts where the impacts of tourism were considered to be more negative, residents nevertheless expressed appreciation for the leisure and cultural amenities available in their local area.
- The vision of Budapest becoming a smarter city is supported by the majority of residents (including elderly residents, but they are hesitant about using smart services). Residents appreciate utilitarian and functional smart services (e.g. e-ticketing or mobility apps). Overall, concerns regarding the deleterious impacts of touristification are predominantly confined to specific districts in the city centre, thereby necessitating targeted management interventions in those areas.
- The lowest-ranked issues in this research—economy, health, education, and housing—generally extend beyond the scope of city governance control.
- As presented in Figure 3, residents living in districts that are located in the so-called 'party quarter' discussed earlier (e.g. VI and VII) and in the heavily visited districts of V (where the Parliament building is located), I (the Castle area), and the increasingly popular District VIII (e.g. where the Hungarian National Museum is located) often rated the impacts of tourism as more negative. This is especially true of District VII (see Figure 3). On the other hand, these areas showed the highest ratings for cultural facilities and attractions.
- Residents show widespread support for smart city development despite potential discrepancies between intended and actual usage of smart tools (e.g. among older residents).

The research suggests that smart technologies could help to effectively manage tourist flows and improve quality of life for residents.

- The research examines critical domains of smart living, including housing, health, safety, education, environment, social cohesion, leisure, culture, and tourism, alongside their corresponding indicators. Through methodological review of previous studies, this research provides a foundational framework for smart city questionnaire design.
- Our findings provide practical recommendations for urban planners and policy makers about that most important quality of life issues, the most preferred smart services, and gaps in residents' needs and interests. Urban researchers and policy makers can utilize our SC scale to evaluate residents' quality of life. Although findings are most directly applicable to post-socialist cities with similar growth patterns to Budapest, our findings and the tools offer broader utility for any city prioritizing smart living as a mechanism for enhancing QoL.

Figure 3. Opinions about leisure, culture and tourism in the most heavily touristed districts of Budapest



In addressing the research gaps previously identified in smart cities literature, this Thesis contributed to the underexplored area of smart cities and quality of life, specifically focusing on citizens' needs. Previous literature on smart city-related quality of life focused mainly on technological and economic aspects of smart cities, whereas this study prioritised social aspects and residents' needs. This citizen-centric approach aligns with Szarek-Iwaniuk and Senetra's (2020) Smart City 3.0, which places citizens at the centre of urban development initiatives, and Wang and Zhou's (2023) assertion that successful SC transformation and meaningful QoL improvements depend on cities' simultaneous investment in both technological infrastructure (ICT) and human capital resources. The results show that residents are most concerned about the smart living domain, especially housing, healthcare and cost of living in smart cities. They are ambivalent about environmental issues, whereas they are relatively positive about social issues, leisure and cultural provision. The most popular smart tools are connected to smart mobility, especially public transport usage. The study provides recommendations that could help to inform city planners and managers about the most important quality of life issues, the most used smart services, and gaps in residents' needs and interests.

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