Smart Cities: Catalyst for Sustainability and Health

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Abstract. The concept of smart cities has gained momentum as a means to address urban challenges and improve the quality of life for residents. This article delves into the intersection of smart city initiatives, sustainability practices, and public health outcomes. Drawing on research and case studies, we explore how smart city technologies and strategies can promote environmental sustainability, enhance public health, and create more livable urban environments. We are interested in whether there are statistically significant differences between participants of different ages regarding the observed parameters related to the mentioned components. The rapid urbanization and population growth experienced globally have led to significant challenges in managing resources, infrastructure, and the overall well-being of citizens. In response to these challenges, the concept of "smart cities" has emerged as a promising approach to address sustainability and health concerns.

1 Introduction

Smart cities represent a paradigm shift in urban development, leveraging technology and data-driven solutions to optimize resource management, infrastructure efficiency, and citizen well-being. By integrating sustainability principles and health considerations into their design and operation, smart cities have the potential to mitigate environmental impacts, promote healthy lifestyles, and foster inclusive communities. As noted by [1], smart cities are characterized by their use of information and communication technologies (ICT) to address urban challenges and enhance quality of life. Smart cities leverage advanced technologies, data-driven decision-making, and integrated systems to create more efficient, livable, and environmentally-friendly urban environments [2].

Green infrastructure, renewable energy systems, and sustainable transportation are integral components of smart city sustainability efforts. Research by [3] highlights the role of smart technologies in reducing energy consumption, lowering emissions, and promoting eco-friendly practices within urban environments. By prioritizing sustainability measures, smart cities can mitigate climate change impacts and create resilient, low-carbon communities.

The health benefits of smart city initiatives extend beyond environmental improvements to encompass public health outcomes [4]. Studies by [5] emphasize the positive effects of green spaces on mental health, physical activity levels, and overall well-being. Smart transportation systems, such as bike-sharing programs and pedestrian-friendly infrastructure, contribute to reduced air pollution, noise, increased physical activity, and improved cardiovascular health.

Smart city planning incorporates green spaces, urban forests, and nature-based solutions to enhance the livability and sustainability of urban areas [6]. This not only improves air quality and biodiversity but also provides recreational opportunities and contributes to the overall well-being of citizens [7]. Smart cities utilize sensor networks and real-time data analysis to monitor air quality and implement targeted interventions to improve it. This includes the deployment of air purification systems, traffic management strategies, and the promotion of clean energy sources [8]. Smart cities leverage data analytics and digital health technologies to enhance disease surveillance, early warning systems, and emergency response capabilities. This helps to identify and respond to public health threats more effectively, improving the resilience of urban communities [6]. Smart cities strive to provide inclusive and accessible healthcare services through telemedicine, remote monitoring, and the integration of digital health technologies. This improves access to healthcare, especially for underserved or vulnerable populations [9].

While smart cities offer significant potential for sustainability and health, there are also challenges that need to be addressed, such as data privacy and security, digital divide, and the need for comprehensive governance and stakeholder engagement. Addressing these challenges is crucial for the successful implementation and long-term sustainability of smart city initiatives [2].

While smart cities offer promising solutions for sustainability and health, challenges such as data privacy concerns, digital divide issues, and financial constraints must be addressed. By fostering collaboration among stakeholders, policymakers, and researchers, smart cities can capitalize on opportunities

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for innovation, economic growth, and social equity. As highlighted by [10], smart city initiatives should prioritize inclusivity, accessibility, and community engagement to ensure equitable outcomes for all residents. In this paper, we focus on smart city components health and sustainability. We are interested in whether there are statistically significant differences between participants of different ages regarding the observed parameters related to the components mentioned.

KEY COMPONENTS OF A SMART CITY THAT CONTRIBUTE TO SUSTAINABILITY AND HEALTH

Many scholars have divided the idea of a "smart city" into several characteristics and dimensions in an effort to better define it, citing the difficulty of managing the smart city idea holistically as justification [11]. From the articles researched, [12] developed a diagram that presents the key important dimensions of a smart city (Fig. 1).

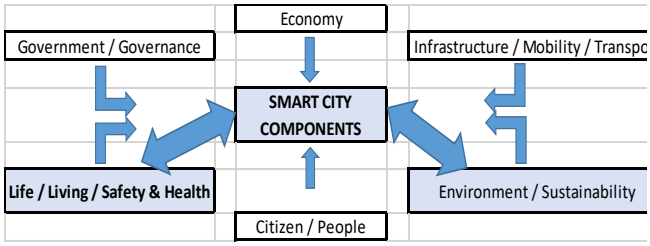

Fig. 1. Smart City Components (source: adapted from [12])

In article we focus on smart's city component Life / Living /Safety & Health. This element encompasses various aspects of individuals' quality of life [13] and enhances it by transforming their residences, communities, workplaces, energy sources, and transportation systems into eco-friendly environments. Smart living enhances people's awareness of how societal dynamics and technological advancements synergize for their benefit. Consequently, smart living involves embracing elements that contribute to a fulfilling and enjoyable existence [14]. Factors such as existing cultural resources, living conditions, educational facilities, tourism, and social cohesion are all indicative of smart living [15]. Citizens utilize technology to create smarter lifestyles, where interconnected devices streamline tasks, making them more convenient, secure, and cost-effective. Recent innovative solutions aim to enhance people's lives by increasing efficiency and promoting environmental sustainability [16].

The concept of smart buildings, focusing on residents' well-being, aids in personalized services and daily tasks, emerging as a prominent trend in recent years [17]. From a health perspective, the adoption of smart technology has positively impacted citizens during the pandemic, enabling them to monitor their health, stay connected with family and healthcare providers, and foster a sense of independence, security, and safety. There is a growing interest in developing smart communities that are resilient both financially and ecologically to natural disasters and human-induced challenges. The COVID-19 crisis has underscored the importance of building resilience in smart cities [6].

Healthcare professionals can deliver more efficient patient care, prevent diseases, and reduce their prevalence through the use of smart health technologies and telemedicine, as highlighted by [18]. Smart health initiatives also help reduce healthcare costs for the expanding elderly population [19]. While effective utilization of smart technologies enables seniors to integrate into modern life and access a technologically advanced and convenient lifestyle, some may feel overwhelmed by new technologies [19]. Addressing this issue is crucial, and local governments should prioritize it, given the limited services tailored to the aging population [20].

Potential solutions include partnering with non-governmental organizations to provide smart devices to seniors in need and implementing programs to familiarize them with technology and e-government services [21]. From digital tools integrated into local healthcare systems to the significant impact of Artificial Intelligence (AI) and security cameras on personal safety, this aspect of the smart city framework is highly visible and can profoundly influence how residents perceive their municipality. Cities worldwide that have successfully implemented the Smart Life/Living/Safety & Health component often rank high in global livability indices, attracting more visitors, businesses, and individuals seeking to work or reside there.

In article we focus on smart's city component Environment / Sustainability. This component pertains to the conservation of natural resources, such as water, land, and clean air. It involves utilizing natural resources in an environmentally sustainable manner, safeguarding the natural habitat, reducing pollution, and managing resources in a more sustainable way [14]. In the twenty-first century, there has been a shift in focus from evaluating sustainability to pursuing smart city objectives.

Green spaces and parks in urban areas are commonly associated with the environment in the context of Smart City initiatives. While these are undeniably important, they do not constitute the entire system. The environment, whether natural or built, is poised to be integrated with intelligent technology that will facilitate effective human interaction with it [22]. This intelligent technology can assist municipalities in waste management by incorporating sensor-equipped and solar-powered facilities. Areas like air quality control and smart lighting benefit from technology use, leading to a reduced negative impact on the environment [23].

2 Methodology

The method used is based on a questionnaire [24], which was compiled as part of a wider research [4, 6]. Regarding the satisfaction of the positive effect of the

observed resource, the participants use a five-point Likert scale from 1 (completely dissatisfied) to 5 (very satisfied) to assess the importance of the observed parameter of residential real estate or living environment where they live. Statistical analysis includes factor analysis of the questionnaire, reliability analysis of the questionnaire (Cronbach's alpha), descriptive statistics and analysis of variance.

Factor analysis plays a crucial role in evaluating participant satisfaction levels regarding residential properties and living environments by identifying underlying relationships between the measured variables in the questionnaire. Specifically, it helps reduce the complexity of the data by grouping related variables into factors, which represent broader dimensions of satisfaction. These factors may include aspects such as the quality of housing, neighborhood amenities, safety, and accessibility. By doing so, factor analysis allows researchers to discern which aspects of the living environment most significantly impact overall satisfaction. Furthermore, factor analysis enhances the interpretability of the results by highlighting the most influential variables within each factor. This enables a more nuanced understanding of how different components of residential satisfaction interact and contribute to the participants' overall perceptions. In this study, factor analysis provides a structured method to evaluate the participants' satisfaction levels, ensuring that the analysis is not overwhelmed by too many individual variables, thus leading to clearer, more actionable insights.

The set of the questionnaire measuring satisfaction with the residential property includes 14 variables, and the set of the questionnaire measuring satisfaction with the living environment includes 17 variables.

473 Slovenian participants took part in the survey. We used the snowball method [25] in data collection in the second phase. The snowball sampling method, while advantageous in accessing hard-to-reach populations, poses challenges in maintaining control over the sample composition. This method relies on participants recommending others, which may lead to sample bias. The risk of homogeneity increases as individuals within the same social or professional networks often share similar characteristics, behaviors, or opinions. Consequently, this can reduce the diversity of the sample and limit the generalizability of the findings. Furthermore, the reliance on personal recommendations may lead to the over-representation of specific subgroups, which impacts the external validity of the study.

Despite these limitations, snowball sampling remains useful in qualitative research, particularly in exploratory studies or when targeting niche populations. To mitigate potential biases, researchers can implement strategies such as setting clear criteria for participant selection or using initial seeds from varied backgrounds. Additionally, triangulation with other data collection methods can enhance the robustness of the results, thereby improving both the reliability and validity of the findings.

3 Results and interpretations

The results were statistically analyzed using analysis of variance. Variance analysis is a frequently used statistical method in research. statistical test, like the t-test for independent samples, except that in the analysis of variance, the means of three or more groups can be compared with each other. As dependent variables, we observe the age of the participants in relation to their expressed satisfaction with their well-being. We observed the feeling of their health regarding to their age, self-assessment of health, and in relation to the parameters of the smart city in terms of health, safety, sustainability and a healthy living environment (natural lighting, air quality, noise, green and natural environment, feeling of security, feeling of a healthy living environment).

		N	**Mean**	Deviation	Std. Error
Feeling about health regarding to my age	1: 35 years or less	141	**3.09**	0.732	0.062
	2: from 35 to 65 years	171	**3.63**	0.751	0.057
	3: 66 years and more	161	**3.43**	0.731	0.058
Self-assessment of health	1: 35 years or less	141	**3.76**	0.844	0.071
	2: from 35 to 65 years	171	**3.63**	0.833	0.064
	3: 66 years and more	161	**3.17**	0.795	0.063
Satisfaction with natural lighting	1: 35 years or less	141	**4.18**	0.997	0.084
	2: from 35 to 65 years	171	**4.50**	0.754	0.058
	3: 66 years and more	161	**4.51**	0.663	0.052
Satisfaction with air quality	1: 35 years or less	141	**4.16**	0.997	0.084
	2: from 35 to 65 years	171	**4.13**	0.994	0.076
	3: 66 years and more	160	**4.37**	0.782	0.062
Satisfaction about noise pollution	1: 35 years or less	141	**3.89**	1.131	0.095
	2: from 35 to 65 years	171	**4.19**	0.994	0.076
	3: 66 years and more	161	**4.37**	0.849	0.067
Accessibility to a green, natural environment	1: 35 years or less	141	**4.58**	0.699	0.059
	2: from 35 to 65 years	170	**4.52**	0.851	0.065
	3: 66 years and more	161	**4.50**	0.823	0.065
Feeling of security	1: 35 years or less	141	**4.57**	0.768	0.065
	2: from 35 to 65 years	170	**4.62**	0.721	0.055
	3: 66 years and more	161	**4.32**	0.918	0.072
Feeling of healthy living emvironment	1: 35 years or less	141	**4.29**	0.815	0.069
	2: from 35 to 65 years	170	**4.41**	0.832	0.064
	3: 66 years and more	161	**4.35**	0.875	0.069

Tab. 1. Structure of participants according to demographic characteristics by age

Statistically significant differences according to the age and observed parameters are shown in table 2.

	Sum of Squares	df	Mean Square	F	Sig.
Feeling about health regarding to my age	23.283	2	11.642	21.357	0.000 ***
Self-assessment of health	29.207	2	14.604	21.518	0.000 ***
Satisfaction with natural lighting	10.241	2	5.121	7.860	0.000 ***
Satisfaction with air quality	5.244	2	2.622	3.041	0.049 **
Satisfaction about noise pollution	11.301	2	5.651	5.744	0.003 *
Accessibility to a green, natural environment	0.577	2	0.289	0.453	0.636
Feeling of security	8.773	2	4.386	6.740	0.001 *
Feeling of healthy living emvironment	1.025	2	0.512	0.723	0.486
* the difference is statistically significant ($p < 0.05$)					
** the difference is statistically significant ($p < 0.01$)					
*** the difference is statistically significant ($p < 0.001$)					

Tab. 2. Statistically significant differences according to participant’s age and smart city components

The results show that statistically significant differences according to age can be seen in expressed satisfaction with one's well-being and self-assessment of health. The results show that the highest agreement is expressed by the middle generations (agreement rate is 3.63) and the

lowest by the younger generation (agreement rate is 3.09), which is somewhat surprising. Regarding self-assessment of health, on the other hand, the highest level of agreement is expressed by the youngest participants (3.76), and the lowest by the oldest (3.17). Regarding environmental parameters such as natural lighting, air quality and tranquility (noise-free environment), the highest levels of agreement are expressed by older participants, and the lowest by the youngest participants. Regarding expressed satisfaction with the green environment, the results are the opposite. Regarding the sense of security, the highest level is expressed by the middle generation (4.62), and the lowest, as expected, by the older generation (4.50). Regarding the feeling of a healthy living environment, the highest level is expressed by the middle generation (4.41), and the lowest by the youngest generation (4.29). Regardless of the statistical significance of the difference regarding the age of the participants, the results show that the expressed satisfaction with the observed parameters is above average, which means that the participants are satisfied with the observed components of a smart city that contribute to sustainability and health.

4 Conclusion

In conclusion, smart cities represent a transformative approach to urban development that integrates sustainability, health, and technology to create vibrant, resilient communities. By adopting evidence-based practices, fostering interdisciplinary collaborations, and engaging citizens in decision-making processes, smart cities can pave the way for a more sustainable, healthy, and equitable future. As we navigate the complexities of urbanization and climate change, smart cities offer a beacon of hope for building thriving, livable cities that prioritize the well-being of both people and the planet.

Slovenia, stands out as a prime example of a smart, green, and sustainable city with a strong focus on health and well-being. Smart cities have the potential to be a powerful catalyst for sustainability and public health. By leveraging advanced technologies, data-driven decision-making, and integrated systems, smart cities can address pressing urban challenges, promote environmental sustainability, and enhance the overall well-being of citizens. As the world continues to urbanize, the adoption of smart city approaches will be crucial in creating more livable, resilient, and equitable urban environments.

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