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Combating Climate Change through Smart Innovations

Examination of smart city concept in light of sustainability

Doctoral dissertation

Supervisor:

Dr. Ágnes Zsóka
(Professor)

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THESIS ARTICLE

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1. RESEARCH BACKGROUND AND RATIONALE FOR THE TOPIC

The main topic of the research is the examination of the environmentally-conscious applicability of smart solutions in urban environments that suffer the consequences of climate change to a great extent. The milieu of the research is set by the relationship of the Earth and Humanity, which has a highly complex linkage with unpredictable outcome. The Earth's resources and capability are at its limits, while the Earth's population is rapidly growing and exploiting its benefits the most. The inequal distribution of resources (food, water, arable land, capital, labour, etc.) and the different level of exposure to risks divide the globe. Still, it can be stated that poverty, famine, inequality is some of the most significant problems that the world leaders, international organisations have not been able to solve for centuries. These unattended problems have been spilled over and intensified the risk of weak institutions, non-inclusive educational systems, gender preference. While some of the societies are suffering from hardship, the other part is responsible for overconsumption, enormous waste generation pollution. This division is tangible in the available opportunities in the field of like economy, healthcare, safety, and labour force. By considering these indicators people can decide for migration to where they assume beneficial conditions. According to the driving circumstances this migration can happen within the country (from rural to urban – urbanisation) or to another country.

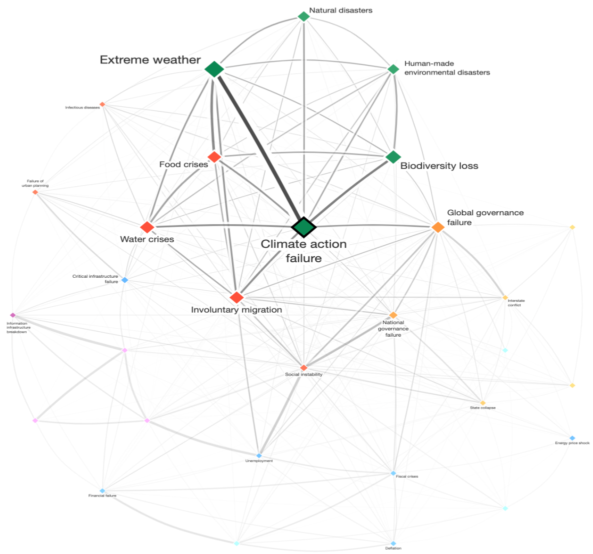
All elements of the human crisis have its ecological consequences. The currently known ecosystem is drastically changing by constantly losing its biodiversity, as a consequence of deforestation (which means a permanent reduction of trees and/or a drastic shift in land use mainly caused by agriculture purposes, anthropogenic forest fires, infrastructure developments (Jayathilake, et al., 2021)) and land degradation (such as aridity, vegetation decline, erosion, salinization, or organic carbon decline of the soil etc. (Pravalie, et al., 2021)). Some species are infested, some are perished by losing their natural and safe habitat or by the enormous increase of their natural enemies.

Beside the change in the composition of the flora and fauna, the anthropogenic use of the non-renewable and renewable resources became unsustainable. The exploitation of the oil (Petroleum, Orimulsion), natural gas, coal (collectively called fossil fuels) is continuous, which puts the global energy supply, the national and international mobility systems in considerable danger, and pollutes the air and water. The fourth element of the non-renewable resources is the nuclear energy, which has been labelled as 'green energy' in the EU since July 2022 by the European Parliament. Although, this form of energy is a low-carbon energy source and cannot be excluded to achieve the countries ambitious climate pledges, there is still significant disinclination because of the safety and environmental risks of the technology and the hazardous waste generation (Vossen, 2020). Using these non-renewable resources irresponsibly by the society and the industry, their indirect consequences creating significant damages within the ecosystem and the renewable resources, such as the intensive water use of industrial production deepens global water stress, or the use of significant gases within products contributes to ozone depletion.

1.1. Climate Change

How did these elements combine with human-centred attitude lead to the most crucial situation, Climate Change, in our century of crises?

1. Figure: The Global Risks Interconnections Map 2020



Source: WEF,2020

It could happen, through the complex interconnectedness of crises. Climate Change became one of the most important global problems and could merit this position through its complexity (Figure 1.) (interrelationship between ecological and human problems) and the challenge that its unpredictability gives (Table 1.). Climate change appeared in the list of 'Top 5 Global Risks' in 2011. Regarding likelihood, climate change was perceived as the fifth most likely global risk, while it was perceived to pursue the second biggest negative impact globally (WEF, 2018, p. 6). For 2020, in terms of likelihood, there were only environmental risks in the 'Top 5': extreme weather, climate action failure, natural disasters, biodiversity loss, and finally, human made environmental disasters (WEF, 2020). Although, if we investigate the other risks, which are stated as environmental risks in these reports; we can determine that all have strong connection with climate change, while they are scientifically declared as its direct consequences (European Commission, 2018), namely extreme weather events, such as storms and cyclones; major natural catastrophes – natural disasters, such as flood, drought; biodiversity loss and ecosystem collapse; water (supply) crises.

1. Table Connection between (Ecological – Human) crises and Climate Change

Ecological crisis	Human crisis
Biodiversity loss	Overpopulation
Land degradation: • aridity, • vegetation decline, • soil erosion, • soil salinization • soil organic carbon decline	Poverty;
	Hunger
	Health and wellbeing crisis
	Inequality
Deforestation	Educational gap
Exploitation of non-renewable resources	Gender inequality
Pollution of renewable natural resources	Economic gap and unemployment
Water (supply) stress	Safety - migration
Ozone layer depletion	Overconsumption;
	High energy demand
	Urbanisation
Climate Change (Complex, unpredictable; Interconnectedness) • **Consequences (CQ)** • **Direct CQ:** extreme weather (storm), natural disasters (drought), ecosystem collapse, water crisis. **Indirect CQ:** water stress, food crises, regional conflicts, increasing social instability and large-scale involuntary migration (S), governance failure, interstate conflict, state collapse (GP), unemployment, fiscal crisis, deflation, energy price shock (E), breakdown of critical information infrastructure and networks (T).	

Source: own edition

In recent years, the knowledge about anthropogenic climate change has considerably increased (Pachauri, et al., 2015), which can be confirmed by the worldwide increasing number of publications, research programs, mitigation, and adaptations projects. How the observation and intensity of climate change impacts have become steadily easier and more notable, the concept of Climate Change and its on-going status became widely accepted (Parry, et al., 2007). Despite the fact, there is still significant uncertainty in the entire procession of the change (Latif, 2011), there are perceptible consequences and the scientific evidence about the effects of climate change is increasing. Due to that, decision makers in the international level, country leaders, politicians, and scientists in the national level, became concerned in the changing climate. The global awareness has increased.

Climate Change is currently one of the most urgent global problems, such as hunger, poverty, overpopulation, loss of biodiversity and resources, and environmental pollution. All these problems are interconnected and have economic, social, environmental, and technological perspectives, and a combination of a top-down and bottom-up approach is needed to tackle them. To do so, in 2015 Paris, 196 countries came together and set targets (Nationally Determined Contribution - NDC) for cutting their greenhouse gas emissions according to the Paris Agreement. These targets put a lot of pressure on the countries and their cities and their population too. If countries committed to their pledges, the biggest contributors by sector (energy), by main centre of emission (cities - through the position of the world's economic activity) (Ovington & Houpis, 2018) and while the world is continuously urbanizing, the people should react simultaneously within the mitigation processes.

1.2. Role of the cities, context of the theoretical framework

Cities represent once the majority of the population, while currently 55,71% (World Bank, 2019) of the world population live in cities and for 2030, the urbanization rate will surpass 60% (UN-Habitat, 2020, p. xvi) and the ratio of urban sprawl will increase likewise. This tendency of expanding urban areas causing problem, namely, they are using arable land for urban purposes by decreasing available land for food production or natural GHGs capture, which increases global and even local vulnerability caused by climate change. Secondly, the greenhouse gas (GHGs) emission is the highest in cities, through the enormous use of transportation, overconsumption of products and groceries, the intensive waste generation, and the high energy consumption etc. Finally, cities are the centre of services and production, which activity requires significant use of energy by further increasing the required energy demand.

According to these factors, cities are the excellent testing-grounds (setting, experimentation, development) (Childers, et al., 2014), (Freeman, 2017) for finding new solutions to increase the efficiency of climate change mitigation and adaptation processes. Smart (city) solutions are going to be analysed in a new point of view, in the light of sustainable solutions for climate change. However, the theory of smart city has already had its own scientific and non-scientific supporters and opponents, the idea of using this theory and its solutions for principally to climate mitigation and adaptational purposes is original. This modern point of view could be emerged by the improvements of the information and communications technology (ICT), the collection and utilization of city data to inform decision-makers, the monitoring local systems (emission reduction, quality of air, energy use) and provided solutions for remote control over the local or household systems. These symbiosis between ICT and urbanisation in the scope of sustainability (Townsend, 2013) are expected to play a key role in achieving the climate related objectives of nations.

1.3. Smart City Solutions, the focus of the theoretical framework

To take a closer look of the different approaches toward 'Smart City', various distinguish can be made, such as technology-driven vs. human-driven approaches (Mora & Deakin, 2019) (who/what is in the centre of the smart development), pro-smart city vs. anti-smart city approaches (based on the attitude) and division of approaches based on smart categories/sectors (Malchenko & Smirnova, 2019). In this dissertation Kummitha and Crutzen (Kummitha & Crutzen, 2017) 3RC Framework, **R**estrictive – **R**eflective - **R**ationalistic (or pragmatic) - **C**ritical schools of thought, are used, while it is seen as the most comprehensive approach.

2. RELEVANCE OF THE TOPIC

The discussion of the relationship between climate change, suitability, cities, and smart solutions has been initiated a debate over terms, such as: climate smart city, resilient city, low-carbon city, eco city, knowledge city, information city, etc. The two main concepts became the ‘sustainable cities’ and ‘smart cities’, although all these terms assume that there is a significant cooperation in economic, social, and environmental fields (de Jong, et al., 2015). Finally, the emerging ‘smart sustainable city’ concept was formed and adapted in 2014 by the UN, which term suggests that smart solution can be used in favour of solving environmental challenges, meanwhile the dwellers well-being is increasing and remaining efficient.

The dissertation has three main reasons, which give relevance to its topic and represents its different and new approach, which are the following:

1. The complex consequences of the man-made climate change represent that climate change is an urgent problem, that current leaders and societies should moderate or, from an optimistic point of view, solve. We need to use two outlooks during combating climate change. We must open up for modern technological innovations, smart solutions, that support mitigation and adaptation processes, and we have to implement the climate related point of view in every further development project to moderate our future ecological footprint.

2. The question, whether top-down regulation is necessary, is no longer appropriate. It is needed, but it becomes sufficient with the combination of local bottom – up innovations to combat climate change. The individual responsibility is the source of local best practices, could be adopted in different regions with similar patterns. Through these movements, local bottom-up approaches can lift to national levels, where they can compensate essential failure of states’ interventions (Kent, 2011) or complement to state action. The use of ICT / smart solutions in a local level can open new fields for innovation and development, where this technology has not been used at all or a former not suitable solution was adapted. As one of the supporters of this movement, the dissertation provides some applied smart solutions.

3. A multidisciplinary approach is needed to effectively tackle the consequences of climate change. Smart (sustainable) city concept could fulfil this requirement, while it is combining technological, economic, and social factors. However, the theory of smart city has already had its own (non-)scientific supporters and opponents, the idea of using this theory and its solutions for principally to climate mitigation and adaptational purposes is original and evolve environmental factors into the concept.

3. THE METHODS USED

3.1. The aim of the research

The target of this dissertation is to examine, whether smart solutions through a novel approach can be serve sustainable climate change tackling purposes. For that reason, the main motivations will be explored to define, what factors drive the choices and implementations of smart city solutions and to analyse their focuses. As Satterthwaite said (Satterthwaite, 1997), cities are seen as the best representatives of these actions, while urban sustainability is needed to combine local actions and the reduction of the transfer of environmental costs to other people, locations, time. This research links these two mostly separately analysed fields, climate change and smart city, and tries to identify the empirical aptitude of smart (city) solutions and the relation between the two fields, while climate change consequences encompass all aspects of our life. Thus, we expect that an appropriate solution for this urgent problem, provide an answer for how urban mitigation and adaptation processes can reach a higher level, while the levels of well-being of people and the environment are not getting injured.

3.2. The Research question and the sub-questions

The core research question of the dissertation is whether smart solution can serve as a sustainable climate change mitigation and adaptation tool. The dominance of smart solutions started in the 1970s and for the 2000s it is worldwide available in different levels. The development was seen through the adaptation of ICT technology to reach more efficient operation for cities. In the last couple of years (5-10 years), according to (Höjer & Wangel, 2014) and (United Nations, 2015b), a new phenomenon emerged namely the 'smart sustainable city'. This new approach put the environment in the focus and use ICT, smart solutions for solving environmental problems by remain efficient. Therefore, it leads to the purpose to determine if smart solutions are suitable tools for sustainable urban mitigation and adaptation purposes.

For that reason, three sub-questions have been defined (Table 2.) to support the realization of the research objective, which represent the three levels included in the examination. The first level represents the 'city level', where the following question could be asked "What factors motivate smart city development?" to define the tool sets of the cities. Accordingly, the main motivation factors will be determined based on the urban challenges, the unique approaches to ‘smart city solutions’, and the potential fields to apply smart solutions. The second, projects, level investigates “How does the environment appear in the accomplished smart city investments?” to identify the importance and the appearance of the ‘environmental’ factor in the already implemented smart projects. During the analysis, the form of appearance (independently or in relation to economic efficiency) and the detected related motivation or compelling force will be highlighted. As the focus of the analysis drills down, the examination of the individual level should be included, too. At this level, through the inhabitants’ point of view the urban challenges and their knowledge about ‘smart solutions’ will be tested to answer the following question: “What is the connection between implemented smart city solutions and the environmental awareness of residents?”. Beside the projects (in)direct climate related results, through the education of the dwellers further achievement could be achieved.

2. Table: Research Question and sub-questions

Research Question - What is the role of smart solutions in combatting climate change by increasing the efficiency of urban mitigation and adaptation processes?
S-Q1: Which factors motivate smart city developments?
S-Q2: How does the environmental impact as motivation appear in the accomplished smart city investments?
S-Q3: What is the connection between implemented smart city solutions and the environmental awareness of residents?

3.3. The methodology

Methodological structure of the research

During the methodology selection the goal was to find a suitable method, which is appropriate for answering the research questions, sub-questions. This dissertation develops a framework to analyse the relevance of ‘smart city solutions’ in tackling climate change. By examining the environmental aspects headway, it is analysed, whether the phenomenon ‘smart sustainable city’, which is according to its definition sustainable development through smart technology in cities, is an existing phase in practice of development or just an ‘utopistic’ scientific concept, which was built up from 'smart city' concept without any experimental existence. Furthermore, the dissertation tries to modulate the importance of complex integrated smart development, and the relation between urban challenges and existing smart solution.

These reviewed studies mostly applied deductive approach with quantitative methodology to verify the cities' level of smartness. While the other dominant methodology in these scientific papers is the systematic literature review to observe the development of the term on account of the non-existent homogenous definition and approach of the phrase. Even so (Table 3.), this dissertation uses inductive approach and qualitative methodology, which methodology is rare in the field of smart city /solutions (Lindqvist, et al., 2020), (Kirimtat, et al., 2020), (Molnár PhD, et al., 2021). The research uses explorative methodology such as semi-structured interviews and non- probability sampling methods during the questionnaire. These two methodologies were selected, because they reach the target groups (local government – representative of city, final users – city dwellers) in the most efficient way and contribute to the triple division (structure of the research), These three different levels, city level, project (environment) level, individual level, have their own target groups. The first one is the local government, who has the task and obligation to develop and maintenance the social services, infrastructure, order of the city. They are the representative of cities. The next level is the project level, where still the local government, or city development specialists, or experts and vendors can conclude their point of view about the various projects' main focuses. Finally, the third level is the individuals', where the city dwellers perspective is relevant. In the first two levels, detailed information is needed and the opportunity to explain opinions, way of thinking. For that reason, interviews have been selected as a methodology to collect specific information at first hand with the least possible chance of distorting information. Additionally, through the interviews, where the individual cases had been discussed, and their results could serve or help to generalisation, and this methodology was used during the IESE Cities in Motion Index (CIMI) (Berrone, et al., 2020) model, which was based on 'best practises', and series of in-depth interviews with different stakeholders. In case of the third level, the questionnaire is the selected methodology, while it can reach a significant number of people within the foreseeable future, if the survey's questions are easy to answer and do not take much time to complete the form. These aspects were considered during the compiling of the relevant questions. While there is a hierarchy between the levels, from wide to narrow – city to person, the research first presents the environment (within the EU and locally) of the cities, then it is applied the interviews to discuss two sub-questions, and then the questionnaire to evaluate the third sub-question.

3. Table: Methodological structure of the research

Aim	Method	Measured Variable	Related research questions	Questions
Context and focus of the research	Systematic literature review	Consequence of Climate Change; Role of cities; Smart city phenomenon and approaches	Provides an overall background for the analysis	What is climate change, and how it affects us? What is the contribution of cities in case of climate change? How can 'smart city' be described?
Conceptual background	Benchmark model analysis	Environmental indicators		What are the most common used environmental indicators?
Analysis of the City-level	Systematic literature review Semi-structured interview	Smart city paradigm; Challenge of cities; Climate change awareness; Applied smart solution	S-Q1 , S-Q2	How would you define 'smart city'? What are the most common challenges of cities? Was climate protection also considered during the decision? What smart solutions have been delivered?
Analysis of the Project-level	Semi-structured interview		S-Q2, S-Q3	
Analysis of the Individual-level	Questionnaire	Challenge of cities; Smart city awareness; Smart solutions	S-Q3	What are the most common challenges of cities? How deep is our general knowledge about smart city? What type of smart solutions are existed?

Source: own edition

To strengthen the reliability and validity of the research, the number of interviewees were increased (from 3-3-3 to 4-7-6), and a high number of respondents were collected during the survey (N=550) and different methodologies were applied (systematic literature review, semi-structured interview, questionnaire). The dissertation follows a multidisciplinary approach, therefor it examines the relevance of the research question with a Hungarian (Tamási, Kecskemét,) and an international (Székelyudvarhely, and a Twin city, Sepsiszentgyörgy) cases.

The dissertation based on primer and seconder data sources (under triangulation[1]). The seconder sources can be divided into three groups. The first one is the relevant scientific literature, which includes theoretic information about climate change, cities and smart (sustainable) city, their connection and development. More precisely, the increasing awareness of climate change and how it became one of the 17 significant global challenges (SGDs) that endanger our sustainably existence; the development of IT technology, which introduced the smart city; and the smart sustainable approach to the 21st century by using smart solutions to combat environmental challenges (such as climate change). The second source are the documents, strategies, reports of international organisations, governments, or research institutes about climate change, role of cities, and smart (sustainable) cities. The third source is the different smart (sustainable) city benchmark models' indexes.

Benchmark models comparison

Firstly, the smart city (benchmark) models have be presented, with particular attention to the various indicators, which can be used to frame the main characteristics and thus identify the main motivations during the choice and implementation of individual smart solutions. For that reason nine benchmark models (European Smart Cities 3.0 (2014) (TU - Vienna University of Technology Department of Spatial Planning, 2014), Smart City Wheel (2014) (Cohen, 2014), ISO 37120:2018 Sustainable cities and communities – Indicators for city services and quality of life (ISO, 2018), UNECE-ITU Smart Sustainable Cities Indicators (United Nations, 2015b),which has been developed to the U4SSC model (U4SSC, 2017), EU Reference Framework for Sustainable Cities (RFSC) (European Commission, 2018b), IGC Development Index (Malek, 2010), A.T. Kearney Global Cities Index GCI (A.T. Kearney, 2021), IESE Cities in Motion Index (CIMI) (Berrone, et al., 2020), Cities of the Future Index (CFI) by Easy Park Inc. (Easy Park Inc., 2022), have be compared according to their characteristics, factors and finally indicators, to find those, which appears more than once in these models. These indicators

[1] Practice of using multiple sources of data or multiple approaches to analysing data**A megadott forrás érvénytelen.**.

related to the environmental, more preciously climate change, have been the topic of some questions within the interview about environmental focus of the developments.

According to the result (Table 4.), in GCI and IGC models do not involve neither Environmental nor Mobility related indicators during their examinations. The ISO 37120:2018 (32%) model is dominate in the Environmental sector. Finally, from the 545 indicators, which were covered a broad scale (such as Number of McDonald's and Slavery), 29 indicators could be highlighted, by appearing in the dataset more than once. They represent all six characteristics of the smart city, and 2 of them were directly climate change related and further 8 were environmental related ones.

4. Table: Characteristics and Indicators of the selected Benchmark models

pc. / Indicators (Components)	Characteristics (sectors)						
Benchmarks	**Economy**	**Environment**	**Governance**	**Living**	**Mobility**	**People**	**Szum**
CFI	16	14	3	4	11	2	50
CIMI	13	11	30	21	14	12	101
EU - RFSC	8	22		15		2	47
European Smart Cities 3.0	6	4	3	7	4	4	28
GCI	7		4	6		12	29
IGC	1		13	1		18	33
ISO 37120:2018	12	40	9	20	7	16	104
Smart City Wheel	7	17	10	8	11	9	62
U4SSC	45	17		24		5	91
Szum	**115**	**125**	**72**	**106**	**47**	**80**	**545**

Source: own edition based on TU - Vienna University of Technology Department of Spatial Planning, 2014), (Cohen, 2014), (ISO, 2018), (U4SSC, 2017), (European Commission, 2018b), (Malek, 2010), (A.T. Kearney, 2021), (Berrone, et al., 2020), (Easy Park Inc., 2022)

Semi-structured interviews

In case of the interviews, they were semi-structured online-based interview with mostly indirect open questions to provide opportunity to the interviewees to express their thoughts, they were hold in 2022. The participated interviewees number was 17 (N=17), a total of 4 local governments such as former city manager and currently Head of the cabinet of Székelyudvarhely, the deputy mayors of Tamási, Sepsiszentgyörgy and smart city project leader of Kecskemét; a total of 7 experts in the field of IT security, mobility, energetics, environment and smart city; and finally total of 6 smart solution provider companies from the market (IoT, safety, solar energy, mobility, water safety). They were contacted by email or telephone and asked to participate in the research, regarding their experiences of the smart market. Participants received information about the purpose of the interview and were informed that participation was voluntary. As preliminary action, an interview draft was created with four topics (personal relevance, climate change, smart city, and smart solution) and 10-10 optional questions, and some pilot interviews were held personally in 2021 under reflexivity with smart city, IT security expert and local government. According to the received feedbacks of the pilot interviews the final questions were created. The final interviews were audio recorded and analysed by using an inductive qualitative content analysis. Also, some of the accidentally picked tapescripts of the interviews were revised as a respondent validation by the interviewees. Some of the questions were asked within the questionnaire and during the interviews to modulate the covered fields, like the most dominant challenges of cities etc., and some of the interviews' questions were based on the result of the comparison of the main environmental related indicators of the benchmark models, such as GHGs emission. The released answers (data) are extractions, not verbatim, upon request of participants.

The cities and their representatives were selected according to three factors. Once, the selected cities have similar historical, infrastructural backgrounds and roughly the same size of dwellers compare to big cities (small cities and settlements, less than 200.000 inhabitants). Secondly, they are town cities of each other like Kecskemét – Sepsiszentgyörgy. Finally, they are representing the local bottom-up approaches, the small settlement, while as Kent (Kent, 2011) said, they can lift national levels, where they can compensate essential failure of states' interventions, and through this they could become 'best practices'. In case of the experts, their fields should cover the main sectoral contributor for climate change in cities such as energy, mobility or they should work on one of the related fields of IoT or urban design / smart city development. Finally, in case of the companies, they should provide frequently installed smart solutions.

Questionnaire

The online bilingual (HU-ENG) questionnaire was available online for 12 days in 2022 in Hungarian and in English. During the non-probability, accidental sampling, and during this timeframe 550 finished answers were sent, which was composed of three sources, the questions were asked online through social media platforms such as LinkedIn, Facebook, Instagram. Some of them were groups, which connect smart city expert and/ or people, who are interested in sustainable cities. The questions were a mixture of direct and indirect, open and closed ones like, "*Do you live in a city?"; "Please mark all the problems you have experienced in your city"*, to test the general knowledge of 'smart city' and collect generally known 'best practices smart solutions'. The questionnaire has three attribute related questions (gender, age, city dweller status).In case of the cities' challenges, the non-city dwellers were excluded, and the optional challenges were listed based on the literature (Meadows, et al., 1972), (United Nations, 1987), (United Nations, 2012) , (OECD, 2010), (UN-Habitat, 2011), (Revi, et al., 2014), (UN-Habitat, 2020), (Kocsis, et al., 2016), (Kovács, et al., 2017).The classification of respondents' knowledge about 'smart city' was based on Molnár's work (Molnár PhD, et al., 2021), and were extended with an additional option to avoid "compulsion to comply". In terms of the known smart solutions, all the participants were asked to answer the related questions, whether they know local or international examples. Detailed characteristics of participants are outlined in Table 5.

5. Table: Sample composition

Attribute	*Attribute versions*
Gender	Female: 59,27% (326); Male: 40% (220); Other: 0,73% (4)
Age	0-25: 7,09% (39); 26-35: 27,82% (153); 36-45: 25,09% (138); 46-55: 22,55% (124); 56- : 17,45% (96)
City dweller	Yes: 87,45% (481); No: 12,55% (69)

Source: own edition

4. RESULTS OF THE DISSERTATION

4.1. The Smart city concept from an empirical point of view

Based on the interviews, it can be stated that the cities (supported by the experts and vendors) main motivations, during the smart solution developments, are to create systems or install solutions that contribute to conscious and sustainable resource management, while they are economically efficient and can operate in a self-sustaining manner (Restrictive school). They can provide complex solutions for the exact problems of the city, while also having social utility and increase the cities' appeal (Reflective school). In case of the involved fields, within the answers there were significantly more hard field related solutions, and most of them has (in)direct environmental (climate change) connection, such as emission reduction, reduce the use of energy or increase renewable energy resource generation. Accordingly, the approach of the 'Reflective school', which considers more techno-centric developments in the fields of the mostly technology focused (sub)systems and see the ICT as core element of the smart city, has been represented itself within most of the answers, however, it stood always together with the elements of the 'Rationalistic schools', such as education, well-being, and economic efficiency. The experts added data-driven efficient decision-making and connectedness as key elements to the approach (Reflective school), while the vendors see it mostly ICT driven developments (Restrictive school). In case of the experts' answers, the soft ones were in the majority, like resident engagement, better communications platform, elimination (or reduction) of bureaucracy, inclusion, cultural life. In terms of the hard ones, there were waste management, energy supply, rain-water management, emergency management, mobility – traffic management system, heating systems, health.

Furthermore, the participants were asked, what the main factors were during the decision-making process of the smart projects and divers answers were formed (attractive, liveable, development, saving, protections, sustainable resource usage or cost-benefit principle and legal regulations), but economic efficiency was always a key and dominant aspect. The environmental perspective usually stated as the second or umpteenth most important factor, while the economic efficiency dominates the decisions. In terms of the vendors, the decision is based only on whether the solution has business potential according to the market or not.

In spite of that, environmental perspective is appearing, although mostly just as an EU regulatory requirement within all the projects, which are financed by EU funds, they should have contained calculations in feasibility studies / tenders related environment (GHGs emission, energy savings, etc.). Beside this, some of the cities are omitted to the climate related consciousness, and in those of them have either specifically Climate strategy (Tamási, Sepsiszentgyörgy) or related strategies such as Sustainable Urban Development Strategy (Kecskemét), Sustainable Energetic Strategy and Sustainable Mobility Strategy (Székelyudvarhely) or Integrated Urban Development Plan (Sepsiszentgyörgy).

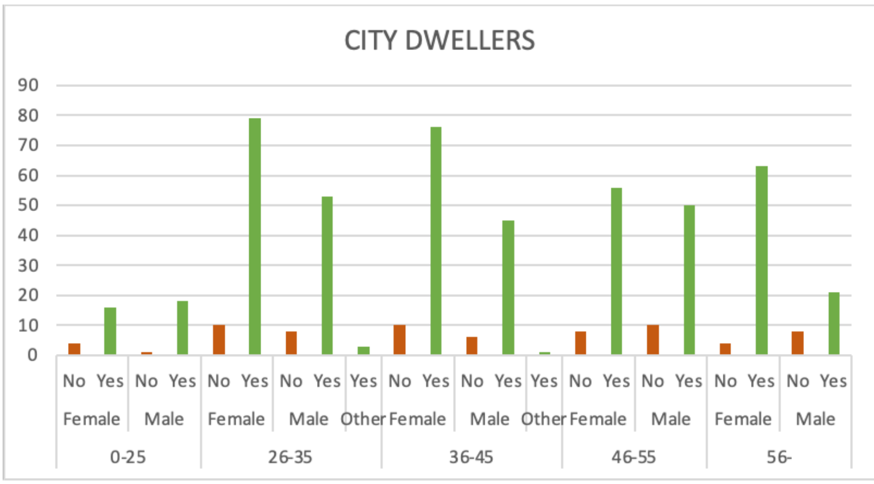
Finally, the examined cities faced with diverse challenges, such as infrastructural facilities related, increasing urban inhabitants, tight financial budget, lack of professional experts and smart solutions can provide solutions just for few of them. Additionally, the cities' representatives, experts and vendors ranked their or generally the cities' challenges, and as a result the three most dominant environmental related challenges were **heat island effect, pollution (air, water, waste, noise, thermal), intensive land consumption**, and they saw the relevance of the smart solutions in case of the **pollution – emission, energy related developments** and within **waste management** systems.

As a result of the analysis, the literature was expanded with 16 new, empirical based definitions about 'smart city', with 13 inhibiting factors during the implementation of an innovative, smart solutions and 4 obstacles from the vendor perspective. As a conclusion, it can be stated that the answers cannot be assigned to a single school, they can be seen as a combination of them, but can be summarized with the thought of Vincent Mosco (Mosco, 2019), like the 'smartness' of a city does not come just with the use of ICT and the adaptation of technological solutions, it should come with the dwellers and citizens. A city is smart (beside the other factors) if its dwellers can use adequately the opportunities of the new solutions and they are aware of the potential risks. Which leads to the appearance of 'environment' in the implemented smart cases, as an eco-efficiency goal. Even, if the cities, local governments, are aware of the importance of the climate change, their exposure to it or the importance of the natural resource protection, the environmental factor usually follow the economic, legal factors.

4.2. Citizen questionnaire on "Smart city" related knowledge

The survey mostly reached female respondent, while the number of female respondents was higher in every age range and in general (Figure 2.). The TOP 3 answers came from the female dwellers of Budapest first one is the 25-35 age range, that followed by the 36-45 one, and the third is the 46-55. Beyond the answers of Budapest participants (all of them were 320), the most answers came from Szeged - Pécs (each of them 7-7), Veszprém - Budaörs (6-6), Érd - Üllő (5-5), Pomáz - Dunakeszi (4-4), Eger-Fót-Kecskemét-Komárom-Miskolc-Sopron-Veresegyház each of them provided three answers.

2. Figure: Division of City Dwellers

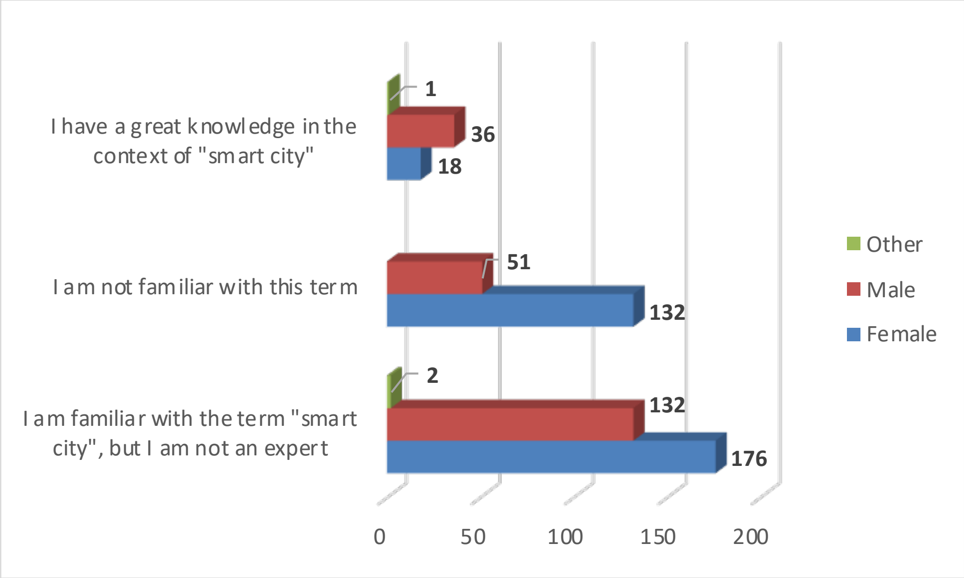


Source: own edition

Based on the literature (Meadows, et al., 1972), (United Nations, 1987), (United Nations, 2012), (OECD, 2010), (UN-Habitat, 2011), (Revi, et al., 2014), (UN-Habitat, 2020), (Kocsis, et al., 2016), (Kovács, et al., 2017), 11 areas were identified as urban challenges and examined in our target. The participants were asked to mark all the problems they have experienced in their city to see what they consider as "challenges". The most important challenges viewed by the respondents is the notable pollution, the heat island effect, and the intensive land consumption. The problem of urban infrastructure is regarded quite considerable, thus the ratio almost reached 50% (it was 49,69%) based on the sample. The participants put the least emphasis on the problems of the energy supply, and placed the Mobility (number of cars, traffic jams, quality and frequency of the public transportation, commute time) and Safety (public security, problem of homelessness) challenges at the end of the list. Besides the evaluation of the current challenges of the cities, the participants were asked to determine type of development would be essential in their cities, settlements. Out of the 362 interventions, which were suggested, the dominating area was green space related wishes and suggestions, and that followed just the mobility (mainly public transport related) ones.

All the 550 participants had been asked whether they familiar with the term 'smart city' (Figure 3). Two of them gave non-related answers, but 310 out of the 548 people, more than half of them (56,57%), considered themselves as who are familiar with this term, 183 people, around one third (33,39%), were not familiar with this term. Finally, 55 people (10,04%) consider themselves, who have great knowledge about the concept.

3. Figure: Which statement is true for you?



Source: own edition

In this research a significant relationship was demonstrated between gender and knowledge of the term “smart city”. More women were familiar with the term 176 (32,29%) compared to 132 (24,22%) men, but more men, 36 (6,61%) had great knowledge than women, 18 (3,3%). All in all, 194 (35,60%) women and 168 (30,83%) men had any knowledge about “smart city”.

As regards the smart solutions, the respondents 19,53% declared that they know a local ‘smart solutions’, while 17,7% of them would be able to identify a solution in a global level. An interesting outcome is that 6 people said they know local and 7 people know global smart solution despite the fact they are not familiar with the “smart city” term. Out of these 107 people, just 104 could list at least one smart solution, while in case of the global level out of 97 positive answers, just 5 could not contribute to the smart solutions examples collection.

It can be stated that the most frequently mentioned smart solutions were different sharing vehicles (car, bike, scooters, rollers), smart bench, smart pedestrian crossing, parking apps, and e-ticket and smart traffic management systems. These solutions contribute mostly to the individuals’ utility (bench, parking app, pedestrian crossing), while the environmental related solutions were mentioned significantly less. They were the solar panels/cells, tools which support the use of renewable energy resources.

Out of the 13 environmental related examples (Table 5.), four (the most) were received from city dwellers, at least 56 years old women, who consider themselves as non-familiar with the term of 'smart city', but can describe a smart solution. In case of the solutions with individuals' utility focus, they came (six – the most) from those female city dwellers, who are also not familiar with the term, but can describe a smart solution and their age is between 26-35 years, which is followed with 4 given examples the 26-35 years old female city dwellers, who are familiar with the term of 'smart city' and can give an example. According to those given answers, which conclude both environmental and individual example, the most answers (eight) came from the 'not familiar' group (four out of five cases). In this classification, the male participants are dominate, while the most answer (8) came from 26-35 years old, male city dwellers, who can give an example, even though they consider themselves as 'non-familiar'. Finally, this is the category, where the self-proclaimed experts' answers were significant (6), in the 46-55 age range. Although, most of the smart solution examples were received from the city dwellers, they were hard on themselves, as they considered their knowledge deficient in terms of 'smart city'. However, they were able to provide 10 environmental cases, 27 individuals' utility driven solutions, while in 49 cases both types were represented in the given answers.

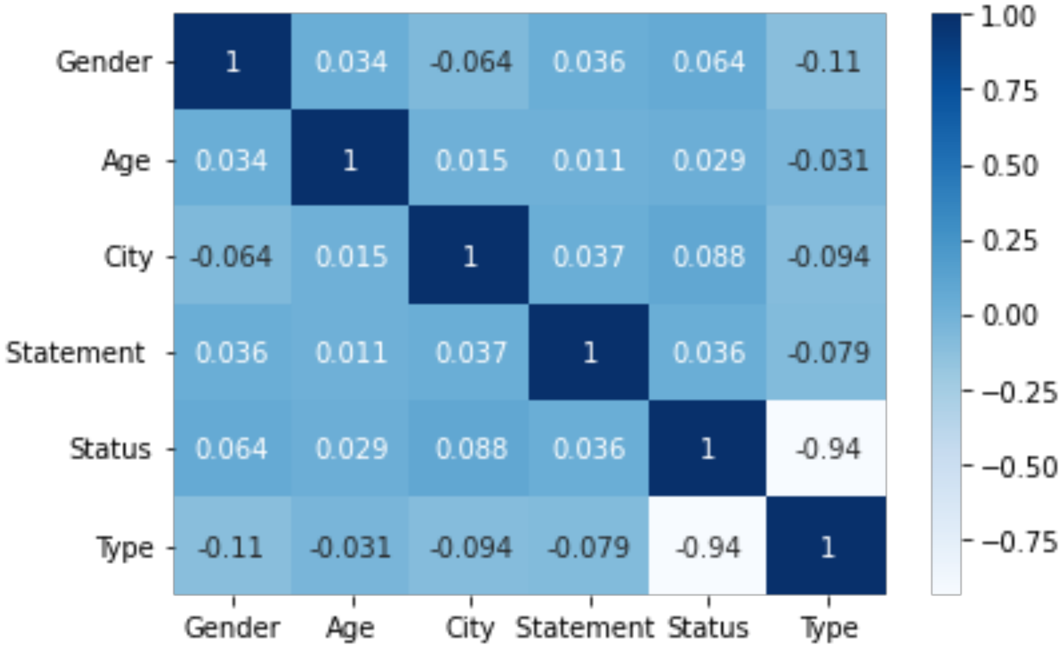
6. Table: Distribution of smart solution types

	Both	Env	Ind	None	Other
City dweller	**75**	**11**	**47**	**343**	**5**
Expert	**24**	**1**	**10**	**12**	**3**
46-55	**7**	**0**	**4**	**1**	**1**
Male	**6**	**0**	**2**	**1**	**0**
Yes	6	0	2	0	0
Familiar	**2**	**0**	**9**	**150**	**0**
26-35	**2**	**0**	**5**	**34**	**0**
Female	**0**	**0**	**4**	**25**	**0**
Yes	0	0	4	0	0
Not familiar	**49**	**10**	**27**	**181**	**1**
26-35	**14**	**1**	**8**	**52**	**1**
Male	**8**	**0**	**2**	**17**	**1**
Yes	8	0	2	0	1
Female	**5**	**1**	**6**	**35**	**0**
Yes	5	1	6	2	0
36-45	**13**	**3**	**7**	**42**	**0**
Male	**7**	**0**	**3**	**22**	**0**
Yes	7	0	3	1	0
Female	**6**	**3**	**4**	**19**	**0**
Yes	6	3	4	0	0
46-55	**12**	**1**	**8**	**37**	**0**
Male	**7**	**0**	**3**	**18**	**0**
Yes	7	0	3	0	0
Female	**5**	**1**	**5**	**19**	**0**
Yes	5	1	5	0	0
56-	**8**	**4**	**3**	**32**	**0**
Female	**7**	**4**	**3**	**23**	**0**
Yes	7	4	3	0	0

Source: own edition

Finally, the strongest correlation (Figure 4.) was between the 'status' (can provide an example or not) and the given example 'type' (environmental, individual, both, none, other), although it is not '1', while there were respondents who claim that they are unable to provide a smart example, but they did. Meanwhile, the other categories show weak relations, and for that reason further characteristics, such as educational level, income, etc., should be involved into the research.

4. Figure: Correlation of the characteristics



Source: own edition

4.3. Collection of smart solutions

The target of this chapter was to provide information about existing smart solutions. Whitin smart economy, governance, people, living groups, positive indirect environmental effects can be achieved through the reduction of (paper-based) administration, teaching materials and related commutes. The environmental relevance in case of the mobility was detailed within the group listing, and the target of the smart environment group was supporting environmental development, awareness, and climate tackle. The solutions, which were listed, had been collected from once the participants of the questionnaire, the interviewees of the semi-structured interviews and finally they were results of my own knowledge or research. The compiled cases were divided into six groups, such as smart economy, smart governance, smart people, smart mobility, smart living and smart environment, which follows the previous analyses' structure of the research and based on the category definitions, which were formed by (Lechner Tudásközpont, 2021), (Samih, 2019), (Vienna UT, 2007), (United Nations, 2015b). Some of the cases had descriptions (while they were mostly systems), some of them were unambiguous, that no further explanation was needed (mostly tools). Not all the listed smart solutions have equal utility or environmental influence, but they can be considered as the most commonly available or adapted ones in terms of personal or city users and affects at least one of the six characteristics of a smart city.

4.4. Summary

According to the received results, smart solutions has been used for mitigation purposes most of the cases in the field of mobility, energy, and heating, as a result of a strong economic or environmental related sustainability approach. These solutions are used to alleviate current urban challenges and as a positive externality of them, for environmental protection. Although currently it is not substantially used for adaptation purposes, the potential inherent in the technology is waiting to be used.

In the empirical implementation of the smart solutions cannot be defined by one leading school related to the term. It can be stated that 'smart city solutions' has been put into practice in varied ways within one city, too. The main motivations related to these projects were increasing economic efficiency, developing self-sustaining systems, expenditure reduction, sustainable resources management, social inclusion, increasing liveability, and attractiveness of the city, and the decision-making processes should be data-driven. Furthermore, the results show that a motivating, innovative, open local government is needed to plan complex and inclusive projects. Finally, the outcome of the dissertation emphasises the importance of the improvement of 'smart people' characteristic by education and sensitizing to achieve greater results through smart developments.

Based on the results, the biggest added value can be achieved, through smart solution implementation in the field of pollution – emission, energy supply and waste management systems. Within these segments, the smart solutions serve directly environmental related purposes, so the 'environmental' factors appear during the decision-making process supported by calculations, estimations about the CO_2, GHGs savings or with the creation of climate or related strategies. Despite the fact, that the core decision point is still economic factors, and just those solution can solve environmental issues, which in the first place economically efficient.

In the individuals' level, the city dwellers considering the notable pollution, the heat island effect, and the intensive land consumption, that followed the urban infrastructure as the most urgent problems of the cities, and they need mostly green space related developments and improvement of the mobility system. Although, the main solutions, which reach the final users (city dwellers) are quite limited, and not all have real environmental or economic benefit. There are devices, tools, services, which serve demonstrational purposes, while others, usually hidden, have effect on the efficiency, gain more return, and contribute to sustainability. The city dwellers are more aware of those solutions, which increase their well-being, personal utility.

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