Sustainable smart cities and cognitive mobility

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Abstract— **Sustainability is in the focus of several strategies and policy documents on the global, regional and local levels of administration. This paper focuses on cognitive mobility from the perspective of urban sustainability management in the era of the digital transition. According to smart sustainable development issues and multidimensional resilience on the urban level, it can be pivotal to enhance integrated solutions. It is considered that the different dimensions and levels of sustainability can be related to cognitive mobility. This paper is focusing on the interpretation of a stakeholder-oriented approach related to smart and sustainable urban development regarding the interrelations with cognitive mobility.**

Keywords— sustainability, cognitive mobility, multidimensional resilience, smart sustainable urban development, stakeholder-oriented approach

I. INTRODUCTION

Nowadays, urbanization processes go hand in hand with the dynamic development of information and communication technologies (ICT) and solutions. However, the growth of cities - due to environmental degradation and pollution, intensive energy use, ineffective urban planning, traffic congestion, increasing social vulnerability and decreasing living conditions, and so on - can threaten the sustainability of cities [1]. Meanwhile, ICT has become pivotal in decreasing the recent and possible impacts and risks of urbanization to be able to meet the requirements of sustainability in an innovative way. Digital transformation can paint a picture of utopian cities where futuristic solutions make people live better than ever. In terms of sustainability, the potential of digitalization is still untapped, and the consequences are not exactly predictable.

Transport systems can play pivotal role in the development of urban areas; therefore their sustainability is one of the key elements in achieving urban sustainability [2], [3]. Nowadays, urban development has to face complex challenges related to socio-economic and environmental processes. Cities are complex systems with high information density that is crucial to be able to deal with in order to implement efficient and sustainable decisions. One of the cities subsystem is the urban transport system that ensure the mobility of different types of capitals, materials, goods and people in the cities and among also between different urban areas. Sustainable mobility is a comprehensive objective of transport policy that is related to the "classic" three dimensions or pillars of sustainable development (i.e. environmental, social, economic).

In the last decades, significant researches were focusing on different IT solutions dealing with the hidden potential of cognitive science. Related to this evolution, the term and definition of cognitive infocommunication (CogInfoCom) was also developed [4] that examines the interrelations between the research field of cognitive sciences and infocommunications. The concept of cognitive mobility can be interpreted on this basis. Thus cognitive mobility can deal with the overlapping issues of mobility, digitalization and the aspects of cognitive sciences.

As there is a relationship between smart city and human decisions [5], moreover stakeholders can be identified, who are responsible for changing the status of the transition process towards a smart and sustainable city, identification of these actors is important. The main research questions are whether who can be these key actors and how are they related to sustainable and cognitive mobility as a subsystem of smart sustainable urban development. The recent paper investigates this multidisciplinary area from a stakeholder-oriented perspective with a special focus on sustainability transition on local, urban level.

II. SUSTAINABLE AND SMART URBAN DEVELOPMENT – SMART SUSTAINABLE CITIES

Information and communications technology (ICT) developments impact our daily life and city leaders also notice this phenomenon as there are more and more smart city ambitions in the urban development strategies on national and international levels. ICT and a change of mindset can offer new urban planning, management and development opportunities. A smart or intelligent city is a place where urban functions and services are made more efficient with the use of communication technologies and digitalization, and local residents' involvement. This can also be considered as a new aspect for supporting urban sustainability.

There is no commonly accepted definition of smart cities, the definitions and concepts are really heterogeneous, and this fact is emphasized in several works of literature [6], [7], [8]. In addition, some study highlight that the concept itself is fuzzy and often inconsistent [7], [9]. There can be found different definitions, for instance intelligent city, information city, knowledge city, digital city and ubiquitous city etc., and can be considered as the roots of the smart city concept. Before defining the smart city, the heterogeneity of the expressions, as intelligent, digital cities, which can be the parts of smart cities, needs to be emphasized; however these are not equivalent

concepts. The authors examine the difference between these concepts and finally they write a conclusion that the smart city emphasizes and based on ICT, however is more than just ICT, as in case of intelligent or digital cities ICT is emphasized [10]. Due to this fact, in the literature several definitions can be found, and several authors, based on a comprehensive literature review examine these definitions [7] [11] [12] [13].

Examining the definitions of smart city in different scientific papers and strategic documents, common characteristics, elements can be found, however some of these definitions emphasize different aspects of smart cities. In this process it is necessary to take into account the following conclusion "Although the term smart city is understood as a certain ability of a city and not focusing on single aspect…" [14]. Different aspects and elements of smart cities can be found in the scientific literature, but sometimes the importance of these is diverse.

Reference [12] identifies three core factors of smart city; the first one is the technology, namely the infrastructures of hardware and software; the second one are the people (creativity, diversity, education); and the third one is the institutions, namely the governance and policy [7] [12]. For instance, in connection with the elements of future smart cities, the role of electric vehicles can be emphasized, as one of the most important elements, based on the zero CO2 emission; in this case the evaluating the approach of environmental sustainability was in focus [15]. The role of citizens, the collaboration between different economic actors and (private and public) innovative business models are also highlighted in several studies [11] [16].

That is an important aspect in the different examined definitions, that the three pillars of sustainability appear in the definitions, and the concept of a smart eco-city is referred "as an overarching or umbrella term for various types of cities targeting a sustainable future" [15]. Reference [16] also examines the content of smart cities initiative and concludes that it has to contain the concepts of sustainability and quality of life, in addition emphasis also the place of technological and informational components in the initiative. Concluding the aim of smart city, that is resolving various urban problems through ICT-based technologies related to urban infrastructure, however in a same time they put together the three pillars of sustainability: „Smart cities are envisioned as creating a better, more sustainable city, in which people's quality of life is higher, their environment more livable and their economic prospects stronger" [7].

Nowadays, data-driven urbanism has increasing significance and role in improving smart city performance in line with sustainable urban development [1]. It can be stated according to the smart city concept in connection with sustainable city that smart city definitely can serve different services and tools through modern technology to increase the sustainability level of a city and foster the transition towards sustainable urban development. Several tools, interventions or solutions can support smart and sustainable urban development e.g. resource efficiency, social aspects, innovation, reduction of CO2 emission, nature-based solutions, waste management etc.. Based on this assumption, it can be stated that available technologies in smart cities can be seen as supporting tools for creating sustainable urban systems through future and climate-oriented consumption and production patterns, consequently, smart cities seem to be prerequisites of sustainable urban areas.

III. SMART CITY FUNCTIONS AND THE SDGs

In 2015 the UN "The 2030 Agenda for Sustainable Development" entitled strategy considering the holistic approach of sustainability defined 17 Sustainable Development Goals (SDGs) to foster sustainability transition all over the world [17]:

SDG 1: No poverty

SDG 2: Zero hunger

SDG 3: Good health and well-being

SDG 4: Quality education

SDG 5: Gender equality

SDG 6: Clean water and sanitation

SDG 7: Affordable and clean energy

SDG 8: Decent work and economic growth

SDG 9: Industry, innovation and infrastructure

SDG 10: Reduced inequality

SDG 11: Sustainable cities and communities

SDG 12: Responsible consumption and production

SDG 13: Climate Action

SDG 14: Life below water

SDG 15: Life on land

SDG 16: Peace and justice strong institutions

SDG 17: Partnership to achieve the Goal

The "United for Smart Sustainable Cities" (U4SSC) is a UN initiative. It is coordinated by ITU, UNECE and UN-Habitat, and supported by other 14 UN agencies. The main goal of this initiative is to achieve Sustainable Development Goal 11 (SDG 11): "Make cities and human settlements inclusive, safe, resilient and sustainable" [17] [18]. In the frame of the U4SSC initiative a smart sustainable city definition was developed, which describes such a city as "an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" [18].

The smart city functions are worth examining from a sustainability perspective. The concept of a sustainable city was first introduced in 1992 as it was appeared in 21th Chapter of the UN Agenda 21 (Local Agenda 21), in which it was emphasized that not only the cities should seek answers to their current economic, social and environmental problems in their development programs, but to take into account the challenges

of future generations and in the long run think [19]. The smart city concepts are ICT based on the exploitation of climate change, more and more definitions set sustainability objectives for smart solutions [20]. Sustainable and smart cities are not substitutable concepts, but from the policy presentation it is clear that today that the contribution of smart solutions to sustainable development is expected at the strategic level.

There are many different divisions and categorizations of smart urban solutions. The Smart Cities Wheel was developed in 2012, and recently this is the most cited model for the smart city [21]. This function-based division of smart solutions is also frequently used within the European Union for categorization, such as the European Smart City Model. The Smart Cities Wheel deals with 6 main categories [21]: 1. Smart Living (SL), 2. Smart People (SP), 3. Smart Economy (SEco), 4. Smart Mobility (SM), 5. Smart Environment (SEnv), 6. Smart Government (SG).

Considering the smart urban areas of the Smart Cities Wheel separately, it can be seen that they are also in line with the SDGs (Tab.1.)

TABLE I. SMART CITIES WHEEL CATEGORIES RELATED TO THE SDGS

Smart Cities Wheel categories	The 17 UN Sustainable Development Goals
Smart Economy	SDG 8, SDG 9, SDG 11, SDG 12
Smart Environment	SDG 6, SDG 7, SDG 11, SDG 13, SDG 14, SDG 15
Smart Government	SDG 11, SDG 16, SDG 17
Smart Living	SDG 3, SDG 11, SDG 12
Smart Mobility	SDG 7, SDG 11, SGD 13
Smart People	SDG 4, SDG 11

The objectives of the Smart Economy (SEco) include sustainable economic growth, innovation-oriented development, sustainable industrialization and sustainable production. Inclusive and equal education and lifelong learning fit the aspirations of the Smart People (SP) category. Smart Governance (SG) is related to of the SDG 16, in particular effective, transparent institutions and inclusive and participatory decision-making. By developing a Smart Environment (SEnv) it is able to contribute to safe and accessible water for all, affordable and modern energy, the fight against climate change, and sustainability goals related to the protection of the life underwater and the terrestrial life. The Smart Living (SL) agrees with the UN to achieve good health and well-being and responsible consumption coincides with the lifestyle aspirations of smart cities.

The Smart Mobility (SM) also strives to use clean energy and its solutions can contribute to the reduce the effects of climate change. According to Tab.1. and considering the smart mobility category of the Smart Cities Wheel, cognitive mobility can play an important role in several SDGs such as SDG 7, SDG 11, SDG 13. Thus, it is related from a sustainability management perspective to affordable and clean energy, climate change actions (mitigation and adaptation) and sustainable cities and communities.

IV. SUSTAINABILITY AND COGNITIVE MOBILITY

Different stakeholders of cities present a relevant perspective of the examined topic, namely the role and possibilities of the different actors in building smart, moreover sustainable cities also considering the importance of cognitive issues. These processes are based on smart technologies, involving even more actor into the decision-making and implementation processes. The involvement of these actors is crucial in reducing consumption needs in urban areas, moreover in analysing data from them. Increased demand concerning information from urban dwellers with regards to their consumption patterns can help to make production side more sustainable by applying available technologies from smart cities.

Nowadays, the role of local people as intelligent agents of a city has become more crucial in the practical implementation of smart sustainable city goals enhancing the main aim of the SDG 11. The potential risks of ICT solutions to sustainability can be grasped also from the stakeholders' perspective related to social sustainability namely in terms of equity, fairness, participation, inclusion, privacy, security, polarization, social vulnerability etc. [1].
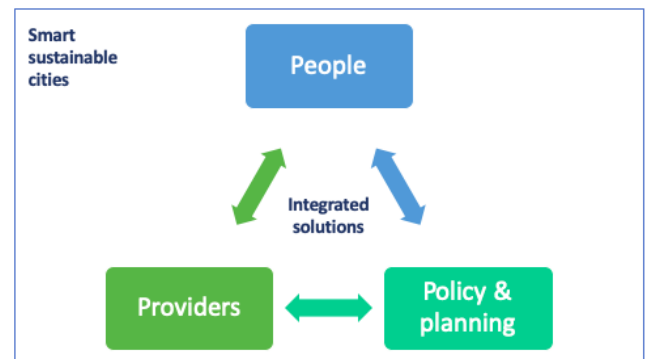

Fig. 1. 3P approach in smart sustainable urban development

According to sustainability and cognitive aspects the stakeholder-oriented approach can be able to deliver an overview and highlight the interrelations between the examined terms in a unique urban subsystem. Fig.1. shows the three main stakeholder groups who can play a significant role in smart sustainable urban development also related to urban mobility as a subsystem.

The 3Ps (People, Policy and Planning, Providers) can support smart sustainable development in different ways (Fig1.). It can be interpreted from several subsystems thus from a sustainable mobility point of view, as well. Based on the different solution sets an integrated solution can be described reflecting the innovative solutions of cognitive mobility and through stakeholders to push progress more effectively towards smart sustainable direction.

A. People

Local citizens or residents, as intelligent agents of the urban environment, also need to have special cognitive skills. Reference [22] defines four main skill categories of the future-oriented citizens, such as cognitive, digital interpersonal and self-leadership skills. Among the cognitive skills belong e.g. critical thinking (e.g. structured problem solving, seeking relevant information), communication (e.g. active listening, synthetizing messages), planning (e.g. time management, agile thinking) and mental flexibility (e.g. adaptability, creativity). Considering sustainable and cognitive mobility, these cognitive skills has increasing importance among the users of sustainable transport systems.

B. Policy & Planning

Recent urban policy and developing processes show a diverse picture from a sustainability perspective [23], [24]. The local government and administration, local decision-makers are the key actors in this category. Effective urban policies should deliver feasible solutions that can foster the practical implementation of sustainable urban development in the era of climate change and digitalization that can be crucial, especially in the 21th century. The question is whether or not digitalization is a solution that can support the transition towards sustainability. There is a lack of cognitive aspects in urban policy development and planning and not only in the case of sustainable transport systems. It can be a hidden potential of future cities.

C. Providers

The providers are able to deliver smart and sustainable, green solutions and innovative ideas, products and services that can enhance cognitive mobility, as well. The transport companies and their maintainers also belong into this category, such as different organizations, companies (e.g. IoT-oriented companies, sustainable businesses, start-ups, manufacturing and service companies, public service companies, cultural organization, NGOs etc.) and special institutes (educational and medical institutes), as well. Cognitive mobility can be related to social and responsible innovation related sustainable business models.

The integrated solutions and approach are crucial according to multidimensional urban resilience in relation to the three stakeholder categories.

V. CONCLUSIONS

The different subsystems of a city can play a pivotal role in the multidimensional resilience of a city due to technical, socio-economic, nature-based and cognitive solutions. Considering smart and sustainable mobility, it can be one of the key elements of smart sustainable urban development that is also able to deal with integrated solution sets, including cognitive mobility.

From management perspective, the stakeholder approach is able to highlight the interrelations between sustainability perspectives and cognitive mobility issues on urban level. Consequently, stakeholders as inhabitants, firms, different providers, government bodies etc. can influence public

management to support the transition towards sustainability in the different urban subsystems.

Cognitive mobility can foster the practical implementation of mobility-related smart city solutions, enhancing sustainability transition in the era of digitalization and can also support overcoming the climate-related challenges or at least adapt to those. Cognitive mobility can provide new possibilities for local stakeholders in future urban development.

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