Examining the Contribution of Smart Homes to the Smart Performance of Cities

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SUMMARY

One of the goals of smart cities is for their residents to live as comfortably as possible, at the highest possible standard of living, and for this, the existence of smart homes is essential. However, smart homes have so far not received much attention in smart city concepts, especially in Hungary. This study discusses definitions of smart cities and smart homes and asks how smart homes can contribute to increasing the performance of smart cities. I created a simplified model based on my search of the literature, which I supplemented with two new factors, which are emphasize the importance of people and education / communication.

Keywords: Smart Home, clever functions, Smart City, smart solutions, Internet of Things (IoT).
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INTRODUCTION

The first smart home controller computer or program was designed in the second half of the 1960s, it was far ahead of its time and was not commercialized. More than five decades had to wait more significant spreading of these systems, which thanks for the internet widespread availability and reliability. While in just a fragment of the traditional property real estate owners have been using the smart apps, in the case of newly built real estate, it is almost essential to have some clever features. The benefits are clear, in the long run, initial surplus investments are likely to return, the overhead costs of housing may be reduced, their comfort levels and their viability can be significantly improved. It is likely that in almost all residences in the future there will be some clever function.

More and more people around the world live in and move to cities. Urbanization is growing rapidly. If we compare cities with rural areas, the concept of urban existence is linked to higher standards of education, health and social services, as well as more active participation in cultural and political life. At the same time, urbanization also brings enormous challenges on the fields of socio-economic development and environmental protection. To cope with these challenges, the latest information and communication technology (ICT) and its available services are needed. A Smart City's ICT offers a concept with sustainable economic development and a high quality of life together with a wise management of natural resources. A smart city ICT infrastructure must be able to integrate the smart homes into a coherent smart city concept, because data from the smart homes will play a vital role in the development of innovative smart city services. For example, data from smart homes can help optimize a city's energy management, increase safety, or make health care more efficient, especially in the area of elderly care. Important elements in this concept are Big Data, Internet of Things (IoT), Clouds of Things (CoT), and Artificial Intelligence (AI).

In 2020 I started a new study focusing on the connections between smart homes and smart cities. My paper is now presenting the first steps of my research. In this paper, I would like to give a brief overview of what we mean by the terms smart city and smart home. The main question of the study is: How can smart homes contribute to increasing the performance of smart cities? This article will introduce a new concept, which I have found on my literature research, where smart homes can be the foundation of smart cities.

Brief Description of History of Smart homes

Technological advancements of the building construction sector in the 21st century have been beyond people's expectation. The emergence of electricity in residential spaces during the previous century was one of the first impetus for this change. This provided a new source of clean and convenient power for appliances. Besides, advancement of IT/ICT was another key player empowering such changes. IT/ICT enabled information exchange among people, appliances, systems and networks (Aldrich 2003). Here is a brief historical timeline to illustrate how these alterations led to the emergence of smart homes.

- The first remote controlled mechanism was built in 1898 (Nicola Tesla's toy boat).
- 1915-20: Many people were at home as a result of unemployment caused by World War I., therefore, the demand for the use of electrical appliances has increased. The electrical home appliances were introduced in this period. For example: food processors and sewing machines. clothes dryers, irons, toasters etc. Most of them were not 'smart' and connected to other appliances, but a few smart appliances were designed before WWII (Hardyment 1988).
- 1920-59: Since women had less time to spend for households during this period - as they had to replace their husbands in their workplaces for a few years - introduction of new home technologies elevated the living standards. For instance kitchens were completely transformed by the appearance of refrigerators, electric cookers, etc.
- 1960-70: The first modern smart home systems were designed in the '60s usually by hobbyists, they were not commercialized, and they were not too popular because of the lack of motivation to increase productivity in domestic work. Developers did not involve the potential users of the technology in the design process, and industry supposed that domestic technology is not enough attractive. In 1966 the ECHO IV Computer was able to compute shopping lists, control the home's temperature and turn appliances on and off (Harper 2003).
- 1980-90: Use of technological/electrical home appliances was widespread by this period. A wide variety of electronic devices became available ranging from cordless/mobile phones to entertaining devices such as PlayStations. Moreower the emergence of Internet allowed numerous new services for example: online banking, shopping and information acquisition. In 1984 by the American Association of House Builders introduced the term 'wired homes' (Aldrich 2003).
- 1990-2000: the emergence of World Wide Web (WWW) inaugurated a new chapter in the history of human achievements. The WWW was first developed by Tim Berners-Lee in 1989. It later became publicly accessible in 1991. In 1993, the first web browser (Mosaic) was introduced publicly. It enabled even amateur users to browse through the World Wide Web without requiring any special technical knowledge (Tuschl 2013). Subsequently, the basic features of modern life began emerging as the result of services delivered through the Internet namely, online shopping, banking, advertising, etc. (Day 2006). 18% of the US population had household Internet access by 1997. This percentage increased to 41.5% by 2000 (File & Ryan 2013).
- 2000-2020: Smart homes, or home automation, started to become popular in the early 2000s as the technology became more affordable and available in commerce. The exponential growth of the Internet continued during these years, enabling the emergence of novel developments in communication, trading, entertainment, education, etc. The term Internet of Things (IoT) was introduced in 1999. It indicated an emerging global Internet-based information architecture facilitating the exchange of goods and services (Wood 2015). Smart objects instrumented with sensing and interaction capabilities/identification technologies such as RFID were developed. IoT strengthens the establishment of smart cities. It enables the integration of smart objects and real world data, forming a digital world (Skarmeta & Moreno 2014). The main drivers of today's smart home systems are security and living greener. The most popular applications are remote mobile control, automated lights, automated thermostats, scheduling appliances, mobile/email/text notifications, and remote video surveillance.

Operationalizing electricity to accommodate shifting lifestyles and spending substantial time outside promoted development of new technological devices catering for the new circumstances. This evolutionary change throughout the times is known as the development basis of smart homes (Aldrich 2003). According to Dingli & Seychell (2015) the term 'smart home' was officially used for the first time in 1984 by the American Association of House Builders. They created a group named Smart House aiming to push forward the inclusion of several innovative technologies in the design of new houses.

Definitions of Smart Home

There is no agreed-upon definition of Smart Home; there are many different ones, they have often different names, some are partly overlapping or similar to Smart Home (remote-home, home automation system, automated home, home energy management system etc.). While the term smart home or smart house is starting to become familiar to the majority of people there is no 100% concrete definition of Smart Home. I have collected a few example of possible definitions:

- Harper defined smart home as "the home which is a well-designed structure with sufficient access to assets, communication, controls, data, and information technologies for enhancing the occupants' quality of life through comfort, convenience, reduced costs, and increased connectivity" (Harper 2003, p.3). This definition demonstrates the benefits that can be expected from a smart home.
- Stresse et al. defined the Smart Home as a private home with many devices of home automation, consumer electronics and so one, which are intelligent. The networking of these devices should generate new services and additional benefits for the residents' (Strese et al. 2010). This definition also focuses on the benefits of smart homes.
- According to Demiris and Hensel, a smart home is "a residence building equipped with technology that facilitates monitoring of residents or promotes independence and increases residents' quality of life" (Demiris & Hensel 2008). This definition highlighted the use of intelligent technologies in residential units to monitor the residents' behaviour for enhancing their quality of life.
- According to ITU (the International Telecommunication Union – United Nation's specialized agency for IT/ICT), smart homes are able to offer various services. These include but are not limited to the regular control of smart appliances (e.g. heaters, air conditioners, washers, etc.), the ability to remotely manage electrical devices, display of consumption data and associated costs, as well as communication between plug-in hybrid electric vehicles and their charging station and on-site micro-generators (e.g. rooftop solar panels) (ITU 2010).

  There are alternative definitions of smart home labelled 'E-home', 'Internet Home' or 'Intelligent living', widely connected with the 'Internet of Things', where every device is connected to the internet and they communicate with each other.
- "Advanced home control systems go by several names, including smart home, home automation and integrated home systems. By any name, these systems conveniently control home electronics and appliances including audio/video, home office, telecommunications, intercom, security, lighting, HVAC, and lawn sprinklers. Control systems can also provide information – residents can find out how much electricity they've used on specific appliances or systems, and utilities can read meters remotely. The systems can be accessed from remote locations by phone or computer, allowing residents to turn on the heat, for example, on their way home from work'" (Marsh 1998).
- 'Home Energy management system is used in the houses as computer-aided tool to monitor the energy and water consumption and control the running mode of home's appliances, fans, lighting and pumps and reset the room temperature in order to optimize the energy performance' (Stavropouloset al. 2014)

In conclusion, smart homes are residential units modernized through a communicating network of sensors, domestic devices and appliances enabling occupants to control the functions of houses through sophisticated monitoring/controlling systems. Implementation of smart homes results in enhanced quality of life, minimized building energy consumption, reduced cost of energy and improved security.

Advantages and Disadvantages of Smart Home Systems

In their research, Mussab et al. distinguished four groups based on the examined literature to determine the benefits of smart homes (Table 1). These four groups are the following: energy conservation; health care; reducing the cost of basic needs; entertainment and comfort (Table 1).

One of the primary purposes of creating smart homes is to conserve energy. The advanced technology provided with IoT devices can reduce energy wastage. These devices improve efficiency and performance while saving energy. For example, there are heating systems that can be controlled with smart devices, so you can control the temperature of your home anytime and anywhere to save energy.

In the case of health care IoT devices can be great help to the elderly and people with disabilities. In many countries, elderly parents do not live with children who can take care of them. In this case a smart home system can help to monitor parents' health status and direct contact is available with a health-care institution (Mano et al., 2016).

These two functions are closely linked to reducing the cost of basic needs, since energy savings and health monitoring significantly reduce spending. For example, because of health-care applications, we need to go to the doctor less often, which reduces our medical costs (Fisher & Hancke, 2014).

As for entertainment and comfort, an IoT based smart home provides comfort and an easily controlled system for the whole house with smart phones or other smart devices.

Table 1.
Advantages and disadvantages of smart home systems

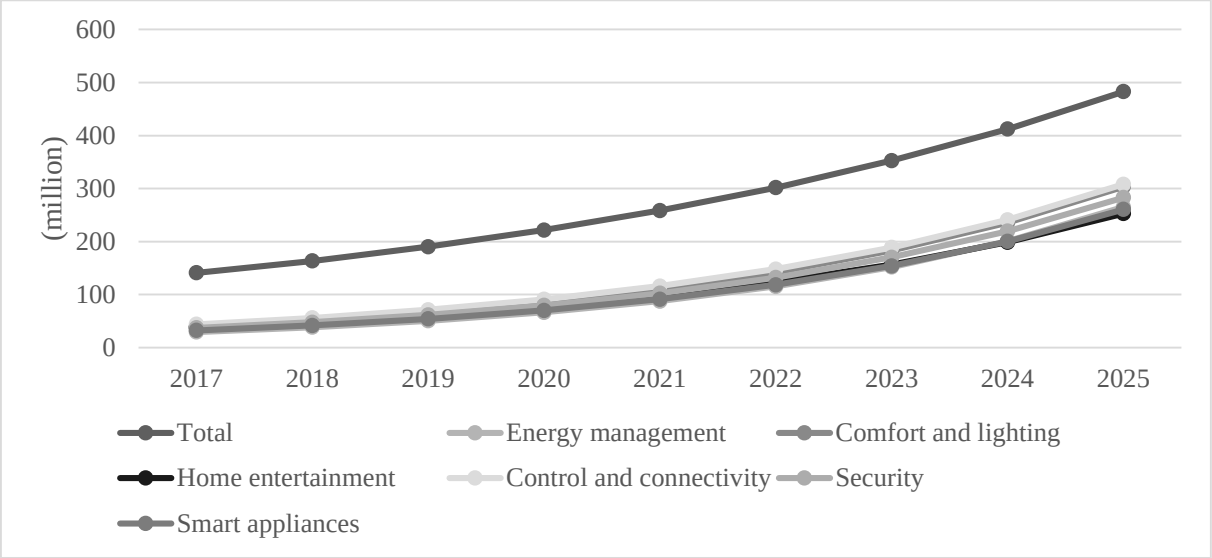
Advantages	Disadvantages (possible barriers)
Optimized energy consumption	Relatively expensive
Real estate value added effect	Lack of experience of using smart home systems
Increased sense of security	Risk of being hacked
Increased quality of life	Complexity
Savings (time, money, energy)	Any damage to the interconnections can disrupt the system
Possibility of convenient features	The technology takes time to learn and get used to. Some people believe it makes life too complicated.

Source: own edition based on Mussab et al. (2017)

Disadvantages of smart home systems include the relatively high price, lack of experience of using smart home systems, and the risk of hacking. There is a great deal of mistrust towards such systems among some people, as no one is happy to disclose their private data.

Directions and Development of Smart Home Systems

Applying the IoT in the context of a private household is what is commonly known as a smart home. The first figure clearly shows the steady increase in the number of smart homes. According to Statista surveys, by 2025, the number of smart homes is predicted to reach nearly 500 million. This represents nearly a quarter of homes worldwide (Statista.com).

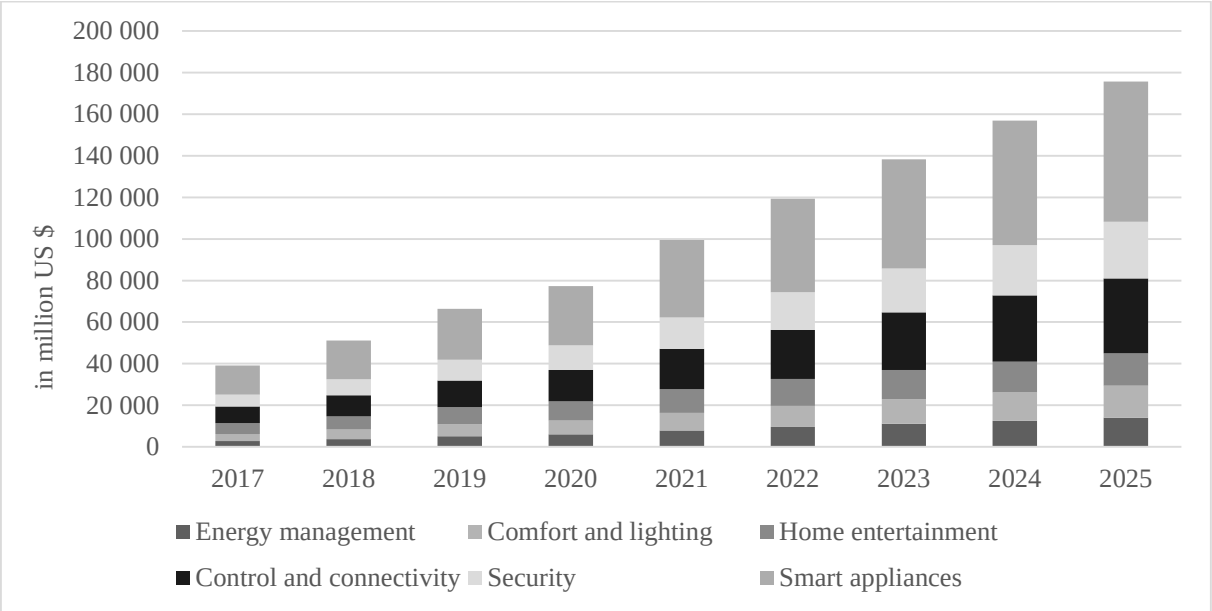


Source: Statista.com, own edition

Figure 1. Number of existing smart homes and homes equipped with a kind of smart solution, forecast until 2025 by Statista.com

Three different phases can be observed during smart home system evolution. In the first phase smart gadgets and their applications are able to collect data, report them, and display them in an organized manner. In Phase 2 the level of data usage is more advanced, and systems are characterized by modelling, notifications and predictive intelligent control. The most advanced smart home systems (Phase 3) are able to adapt and learn their environment (Parks Associates 2014).

Nowadays, there are many kinds of smart home systems and perhaps this is the biggest problem with these systems, as they are generally not compatible with each other. So one of the most important development directions is that these systems become compatible with each other, but this is not in the interest of the companies at the moment (Wood 2015). A useful development path can be the convenient multi-terminal control (built-in, mobile, web-based, PC) on all sorts of visual interfaces that synchronize with each other and provide real-time information and monitoring (Orosz & Péter 2017).



Source: Statista.com, own edition

Figure 2. Annual revenues of Smart Home categories, forecast until 2025 by Statista.com

Figure 2 shows annual revenues of smart home categories. By 2017-2025 an increase of about 135 billion USD is shown. The biggest revenue is clearly from the smart appliances category; nowadays it is about 28 billion USD. Significant revenue also comes from home control systems and from security. The other categories have also increased or are predicted to increase their earnings compared to 2017, so it looks like there has been a lot of progress in this area and it will probably continue in the future.

THE CONTRIBUTION OF SMART HOMES TO THE PERFORMANCE OF SMART CITIES – CAN SMART HOMES BE THE FOUNDATIONS OF SMART CITIES?

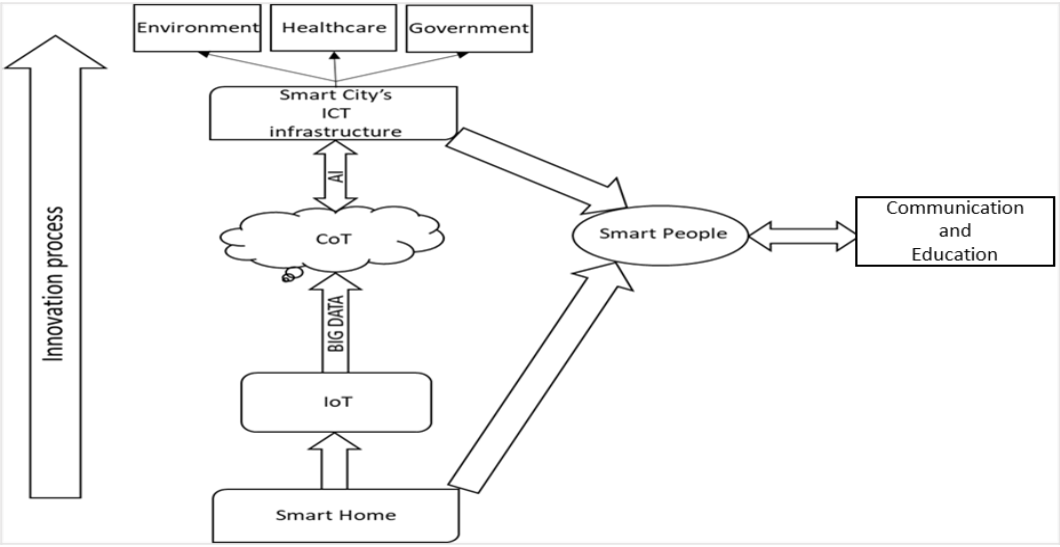
Since the development of the industrial revolution, specialists in the development of cities have been visioning the most advanced technologies in their ideas. The spread of smart technologies improves the quality of life, can contribute to reducing territorial differences within settlements, improving accessibility of urban services, reducing the burden on the environment, and contributing to improving the situation of disadvantaged groups.

The growth of smart city initiatives is unbroken. Cities are trying to solve systemic problems of complex problems, while increasingly complex processes need to be treated simultaneously. The term ‘Smart city’ is relatively new being used only in the 1980s and ‘90s in the literature. Although the expression ‘smart city’ is becoming more widely known – thanks to the rapid development of ICT – there is no commonly agreed definition or concept of its content (Nagy et al. 2016).

One of the best known smart city definitions is that of Giffinger et al. (2007): “a Smart City is a city well performing built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens”. They said that a smart city is a city that has to perform well in six dimensions: smart economics, smart people, smart governance, smart mobility, smart environment and smart living. In the dimension of smart living conditions, the role of smart homes in the life of a smart city was highlighted. Approached from another point of view, however, it can be not only an indicator of a smart home, but can even form the basis of a smart city (Figure 3).

Big data and the way it is used can be the key to smart homes contributing to the development of a smart city.

"Big data is a term that describes large volumes of high velocity, complex and variable data that require advanced techniques and technologies to enable the capture, storage, distribution, management, and analysis of the information." (TechAmerica Foundation 2012)



Source: own edition, based on Skouby et al., 2014

Figure 3. Smart Home as a foundation of a Smart City

Smart homes can play a big role in boosting the performance of a smart city as they produce a lot of data (Big Data) thanks to being connected to the internet (IoT). But this data is just usually used intelligently in just smart homes. The next step should be to turn smart homes into a larger, organic unit, into a smart city. Using Cloud of Technologies (CoT) to integrate the smart homes into a smart city concept creates new sustainable service opportunities, creates a basis for improving the quality of life for people, and forms new ways of implementing city governance. In this vision the CoT technology is a vital player because it handles the huge amount of information produced by the IoT devices. In simple terms a CoT is a pool of resources and calculation capabilities accessible through the Internet. For smart cities combining IoT and CoT is crucial, so that IoT data can be processed and stored (Skouby et al. 2014).

Complementing these two technologies (IoT and CoT) with artificial intelligence, the city management can collect and analyse data from citizens and robotic systems in real-time. A smart city can benefit greatly in many areas from these data, mainly in health care, energy consumption, administration and public safety. In my opinion, in this model one of the most important factors is the "smart" people, or community (who can be able to use smart city's tools, or systems correctly), because without them the whole system would not work. Education and communication are also important factors because a community needs to be able to use applications, systems, but for many smart city projects, a lack of information or communication is also a problem. I would like to present a few examples of why the smart homes are an important part of smart cities:

- **Healthcare:** The population of Earth is quite rapidly aging. According to the UN, the number of older people will make up 56 per cent of the whole population by 2030 and will exceed 2 billion people by 2050: every fifth inhabitant of the planet will be a person who is 60+ years old and life expectancy is steadily increasing in almost all regions. So smart home solutions will be very important in the future, for example in the field of elderly care or in the case of any health emergency. For example: AI detects unusual behaviour like an elderly person has fallen, AI monitors behaviour and informs caregivers in the area of telemedicine, etc. (Skouby et al. 2014).
- **Environment:** When homes are connected to a system with ICT-based infrastructure, artificial intelligence can be used to easily monitor, for example, residents' energy use patterns. Once the samples are available, then the system can schedule and optimize the energy use of each area, achieving local and global savings (money and energy).
- **Government**: Smart home systems are also able to detect unusual patterns of behaviour in our home and can immediately alert the police, or security

companies. This can also have a big impact on increasing public safety in a city.

These examples also show well that smart homes can be a key factor for a smart city in the future. Of course, the technologies that exist today still need to evolve, especially artificial intelligence. Furthermore, these systems must ensure the security of the data, as it can be dangerous if the data falls into the hands of a third party (hacker risk).

CONCLUSION

Due to the widespread of large number of IT applications and the use of the Internet, the functioning of settlements is becoming unthinkable without use of them. Due to technical progress, there may be positive changes in the life of the settlements due to the pressure, but there are quite different paths for settlements and cities which have conscious settlement development, thanks to the tools almost accessible to everyone. As a result, the smart home market is also developing dynamically worldwide. By 2025, a quarter of homes will already have some sort of smart-home solution and these systems may play an increasingly important role in the development of a smart city. After collecting data generated by the population of a smart city, there is a chance to increase the city's performance in a number of areas, such as in the fields of public safety, health care, and energy consumption. If technological progress continues at this level and the Internet of Things (IoT), Cloud of Things (CoT) and artificial intelligence (AI) can be linked with each other, smart homes can be the basis for smart cities. Of course, there are still many things to be solved in this area, such as guaranteeing data security, or creating simple smart home systems that even older people can easily learn to manage. The presented ICT-based infrastructure provides a new platform for services (Figure 3.). It mainly focuses on services in the areas of social programs and healthcare; environment, energy and water; and the area of government, administration and public safety.

The study presents a relatively new approach to the smart city concept, which is also a new topic in the international literature. The point of the approach is that smart homes can be the foundation of smart cities. I created a simplified model (Figure 3.) based on my literature research, which I supplemented with two important factors, which are emphasize the importance of people and education / communication.

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