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Facing urban challenges – Tungsram smart city action plan

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Closed to three-quarters of Europeans live in cities today, and by the growth of the population worldwide, this ratio is ever increasing. The accelerated speed of urbanization poses unprecedented challenges on people, cities, and the environment. Sustainability became a key global objective since Rio via Tokyo until Paris Agreement. The United Nations prepared an agenda for a better and more sustainable future for all. The 17 Goals are related to global challenges such as climate change, poverty, and the effects of urbanization. Over the last decade, various Smart City approaches have emerged among the government, non-profit sectors, and industries to use Information and Communication Technology as a tool to manage these challenges and to improve the quality of life for their citizens. At the same time, Industry 4.0, the digitalization of industries, has diffused across the world, setting the scene for a new stage of innovation yet keeping the competitiveness of business players.

Tungsram, a multinational corporation headquartered in Hungary, has refocused its mission and stood up to expand its product portfolio by including Smart City solutions. Tungsram Edge focuses on three major Smart City offerings: indoor farming, efficient buildings, and Smart Solutions. Indoor farming (AgriTech), a science-based approach to agriculture, uses the latest research to establish precision indoor farming facilities. Efficient buildings (PropTech) has come to life to support the universal goal of reducing cities' ecological footprint. Each smart solution has a direct or indirect effect on several objectives of the Sustainable Development Goals of the United Nations.

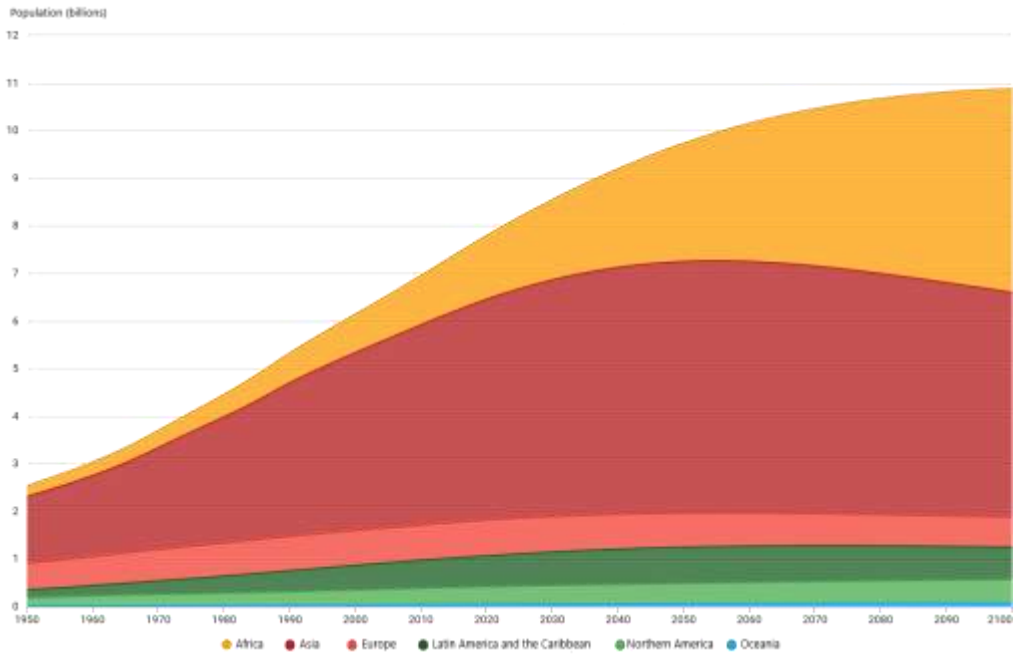
The first part of the paper identifies the key contemporary challenges of cities and industries and the evolution and links of Smart City and Industry 4.0 approaches. The second part of the paper is a case study of a multinational company headquartered in Hungary entering into these processes by building a Smart City Action Plan and by developing key smart products (Smart City portfolio) to react to and to provide solutions for urban challenges.

Keywords: Sustainability, Smart City, Industry 4.0, Tungsram

1. Introduction

By the latest estimation of the *United Nations* (UN) the world population reaches 10 billion until 2100 (UN 2019b). Distribution of population by continents has changed over time. In the forthcoming decades 80% of the future global population growth is expected in Africa (Figure 1). While the continent has approximately 1.3 billion inhabitants today, this number is expected to grow to 4.3 Billion by the end of the century. According to the forecast of the UN meanwhile the 750 million population of Europe in 2020 will decline by 100 million by 2100. The relative weight of our continent in this respect is seriously declining: While in 1950 22% and in 2020 closed to 10% (CSO 2020) of the population of the Earth lived in Europe, this proportion will below 6% in 80 years from now (UN 2019c).

Figure 1 Global population by continents, 1950–2100



Source: based on CSO (2020)

In 2010, the first time in history, there were more people living in cities than in rural areas (UN 2014). About half of all city dwellers live in cities with a population of less than 500,000 inhabitants, while every 8th person lives in one of the 33 megacities that have a population of over 10 million inhabitants (UN 2019a). This trend keeps continuing: less and less people choose to live in rural areas and the growth of the planet's population is increasing the inhabitants of the existing cities and megacities.

This accelerated increase poses unprecedented challenges we are all facing in the world, but it particularly affects cities, where all the environmental, societal, and economic challenges are being concentrated. These challenges can no longer be tackled with traditional methods that once used to offer one-size-fit-all solutions: we need to pull in the new *Information and Communication Technologies* (ICTs) and all the innovative management methodologies in order to keep up, and not only to keep up, but to proactively anticipate the future challenges and solve them before they present themselves. *One of the fast growing approach to handle these challenges is Smart City concept in all over the world.*

In our paper, we investigate what aspects of the global challenges a Hungarian multinational company, Tungsram has determined to tackle, that has transformed itself from a traditional lighting manufacturer into an innovative and smart company by establishing a remarkable smart city product portfolio; and how they address the UN's Sustainable Development Goals (SDGs) that are an integral part of the everyday operations of the corporation.

In the first part of our study, we are going to review the contemporary challenges that cities and industries are facing. In the second part we are going to address why Smart City concept is a relevant approach facing contemporary global challenges. Finally, we are going to present Tungsram's Smart City model at its current stage, which aims to tackle some of the most critical challenges that cities are facing.

2. Contemporary Challenges of Cities and Industries

"As the world continues to urbanize, sustainable development challenges will be increasingly concentrated in cities, particularly in the lower-middle-income countries where the pace of urbanization is fastest" (UN 2015a, p. xxi.). Sustainable development challenges primarily drill down to *environmental issues*, which must be addressed in order to be able to slow down, and perhaps, *reverse climate change*. ICTs, while they help economies to grow and cities to prosper, create more challenges just by solving the previous ones: more efficient and livable cities attract more people, which in turn create even more environmental, social, and economic issues to solve; and once solved they – again – become attractive and prompt for another growth curve. (Figure 2) In this chapter, we are going to examine the circularly evolving challenges that drive the need for cities to be smarter.

Figure 2 Relationship between technology development, demographic shifts and sustainability issues

Source: Nick et al. (2018. p. 66)

2.1. Issues to Solve

"People, and thus populations, are at the centre of sustainable development" (UN 2019b, p. iiii) start the authors of the 26th edition of the United Nations *World Population Prospects*. The latest release confirms that the world's population continues to grow, and while it signals a slower growth rate than previously projected, it is still going to increase from the 2019 population of 7.7 billion to 8.5 billion in 2030 and to 9.7 billion in 2050. While in 1950, only 30% of all people lived in cities, today, it is 55%, and by 2050, it is projected to reach 68% (UN 2019a). The relative volume of the urban population varies in all continents; however, the growth is concentrated in cities everywhere in the world.

"As the world continues to urbanize, sustainable development depends increasingly on the successful management of urban growth, especially in low income and lower-middle-income countries where the most rapid urbanization is expected between now and 2050." (UN 2019a, p. xix) Since economic growth is also shifting from urban areas to cities, we need to increasingly focus on managing cities smarter and more efficiently.

The previous 8 Millennium Development Goals (UN 2015b) the UN had set in 2000 more than doubled: for 2030, they addressed 17 sustainable development goals (SDG17) worldwide in 2015 to face global challenges (Figure 3).

Figure 3 Sustainable Development Goals of the United Nations

Source: United Nations (2019, p. 36)

Some of the objectives are relevant in urban environments. Objective 11, *Sustainable Cities and Communities* is specifically linked to cities. The *UN's Economic Commission for Europe* (UNECE) has also published a guide to action plans for cities to become smart and sustainable[1]. This guide derives the goals to be set specifically from the UN's 17 sustainability goals. The 8th goal *Decent Work and Economic Growth*, the 9th goal *Industry, Innovation and Infrastructure*, and the 12th goal *Responsible Consumption and Production* provide guidance directly to the stakeholders of economic actors.

In the empirical part of our paper, we will see *how Tungsram*, despite being a comparatively small company on worldwide scale, *is able to address over half of these sustainable development goals, directly or indirectly*.

2.2. Enablement

The change in demographics and its concentration to cities pose a new level of challenge to the municipalities, governments, and states. Since there has been an exponential development in ICTs, a reasonable amount of these challenges had proven to be improved: public safety and security, traffic congestions, or energy consumption optimization, just to name a few.

Moore's Law (Moore 1965), which states that computer processing power doubles every two years, *Gilder's Law* (Nick et al. 2018), which declares that bandwidth grows at least three times faster than computing power, and *Ruettger's Law* (Tassebehji 2003), which highlights that companies double their storage needs every 12 months, in other words, the info communication infrastructure that they describe makes it possible that growing cities can tap into the technology they need to keep up with the population growth. And while ICTs are all enablers of growth, they lead to the consequences described in the next chapter.

2.3. Consequences

The exponential growth of ICTs leads to *disruptive technologies* in different industries. *Amazon*, *Uber*, or *Airbnb* are all based on new business models and use *Open Innovation 2.0* (Curley 2016) As ICTs are being integrated into the environmental, economic, and social ecosystem of the cities, they solve some of the challenges.

These concepts, as well as the *innovation management approaches and methodologies*[2], such as *disruptive innovation* (Christensen et al. 2015), *design thinking* (Brown 2008, IDEO 2020, Schoonmaker 2014), *lean startup* (Liker 2004, Ries 2011, Blank 2013), *agile project management methodologies* (Morris 1997, Rico 2019, Davies 2018), *and exponential organizations* (Malone et al. 2014) will play an important role in the case studies described in the empirical section on the Tungsram Smart City Action Plan.

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1 https://www.unece.org/fileadmin/DAM/hlm/documents/Publications/Guidelines_for_SSC_City_Action_Plan.pdf

2 In detail see Pongrácz (2019).

3. Why the Smart City concept?

The megatrends, namely the conflicts of urbanization and environmental sustainability on the one hand, and the exponential advancement of ICTs on the other, led to the development of the Smart City concept. In the introductory chapter, we have outlined why these changes require cities to innovate continuously. *The main drivers of the changes are the expansion of population, the influx of people into cities* (Enyedi 2012), *the growing challenges of environmental sustainability, social inequalities, and the exponential development of ICTs*, which, in some views, provide an opportunity to address these challenges.

3.1. Approaching Smart City

There is a vast number of definitions of smart cities that have been published (Giffinger et al. 2007, Palmisano 2008, Batty 2012, Cavada et al. 2014, Höjer – Wangel 2014, Manville et al. 2014) and analysed (ITU-T 2014, Albino et al. 2015)- They all highlight some of the key aspects of the big picture of the Smart City concept. Such aspects include the use of ICTs, innovation, sustainability, inclusion of community, efficiency, and, for example, transparency. According to the group of researchers led by Giffinger et al. (2007) „*Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens.*" (Albino et al. 2015, p. 6).

Based on the analyses of 116 definitions set by academics, government agencies, corporates, and non-profit organizations, the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) created the following comprehensive definition: „*A smart sustainable city is an innovative city that uses ... ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.*" (ITU-T 2014, p. 13).

Definition created by corporations like IBM, CISCO, Siemens are focusing on the ICT aspects of Smart City. IBM's Smart City approach is not only to engage in the digital transformation of a city's existing systems, but to create a "Smarter City" by comprehensively transforming its "system of systems" (Dirks–Keeling 2009). In the view of IBM based on ICTs, cities may build an *instrumented*, *interconnected* and *intelligent* system. Instrumentation or digitization means that everything is measurable by IT tools such as sensors and hence cities' systems become data points. Interconnection means that the data collected can "talk to each other", so it makes plain data turning into information. Intelligence means the ability to analyze the information thus created and to make strategic decisions.

This approach is very close to that of Tungsram's, as it is represented in its Smart City Action Plan. However, *we developed our own definition* which is more aligned with suppliers of smart city solutions. The Smart City definition *we use for the Tungsram case study* combines the following items:

1. High quality public services, living and working conditions for citizens and businesses;

2. Involving as many citizens in the decision-making as possible;
3. A conscious effort to use scientific and technological tools;
4. Emphasis on the use of info-communication as a key tool;
5. Conscious consideration of environmental, social and economic sustainability, and minimizing vulnerability as a prime constraint.

3.2. Relation of Smart City concept and parallel models

Over the last three decades, several similar concepts have emerged among researchers, government agencies and professionals, i.e. a livable city, a green city, a sustainable city, an eco-city, a resilient city, a digital city, an intelligent city, and many more related nomenclatures. The concept of a smart city can also be seen as an umbrella that conjoins a number of related concepts under it. In some cases, these can be interpreted as a sub-area of the overall smart city concept, in other cases they are more or less a synonym for it. In the following sections, we describe four concepts that we consider relevant to our work.[3]

Green City

On the one hand, a green city literally means a city with a large and high-quality community green space, but on the other hand, its meaning extends to a city having a high priority for environmental sustainability, thus providing healthy living conditions.

When talking about an approach based on environmental sustainability, the term *green* is being interpreted in many different ways various authors (Brilhante et al. 2018). For example, the European Bank for Reconstruction and Development (EBRD) study "Green City Program Methodology" defines a green city as a city that achieves significant results compared to others based on specific performance indicators in the following ways:

- Preserves and improves the condition of available natural resources (air, water, soil, biodiversity) and utilizes them in a sustainable way
- Manages climate change risks and adapts to climate change
- Ensures that legislation relating to environmental sustainability contributes to the social and economic well-being of the population

Creative City

A creative city is a city where creativity is considered a key factor in sustainable urban development. The concept of a creative city has been interpreted in many ways by many scholars. It could be about emphasizing the importance of creativity as a value, but it can also be interpreted as a city where the economic impact of the creative industry is higher than average.

[3] Pongrácz (2020) analyzed 10 parallel concepts in his dissertation. From this list, we selected only four, frequently used synonyms related to Smart City.

An example to the first approach is the idea of "The Creative City" by Australian businessman David Yencken, published in 1988, which triggered a global movement. Yencken explains that while cities need to operate efficiently and fairly, they must, at the same time, encourage the creativity of their residents and provide an emotionally comfortable environment (Yencken 1988).

If we wish to assess the impact of creative industries in a city, then first, we shall define what we call creative industries. The concept of the *creative industry* is not being used consistently in the literature. The picture is further being blurred by the use of the term *cultural industry* with a content very similar to that of the *creative industry* (Keresnyei 2015). But we must note that the cultural industry is a subset of the creative industry characterized by the promotion of cultural values (e.g. cultural tourism, museums, libraries).

Digital City

The digital city is a city that prioritizes the use modern ICTs (IoT, AI, Cloud, Big Data, etc.). The term digital city can also be used as a synonym for the technological approach of a smart city (Tregua et al. 2014). Another interpretation of the term digital city is that it is not necessarily the city itself that employs digital technologies, but it creates an atmosphere that encourages innovation in digital technologies. The *European Digital Cities ranking index* (EDCI 2016) uses this approach and classifies cities specifically from the perspective of the friendliness of the environment offered to startups and scale-up companies that are engaged in digital innovation.

Intelligent City

The term *intelligent city is often used as a synonym for a smart city*, while others mean a dynamic digital urban environment that can adapt to users and the environment, going beyond static buildings and urban infrastructure.

In fact, the term smart city has started to become "occupied" in the world of science and governance since the mid-1990s. In June 1994, the so-called *Bangemann Report* "*Europe and the Global Information Society – Recommendation to the European Council*" was released. The key message of the report is that the appearance of the information society is inevitable, which would lead to another industrial revolution. The latter can be matched with the onset of Industry 4.0 but appeared almost a decade and a half after the Bangemann Report.

The report identified 10 main areas for improvement, including the establishment of a *trans-European public administration network* and an *urban information superhighway* (Lados 2015). The message had an almost immediate effect, the development of *intelligent city, region and country strategies* commenced across Europe in the second half of the 1990s. Intelligent city strategies across Europe have started focusing mainly on laying *the foundations for e-government*, enabling back-and-forth communication with citizens through ICT tools, and expanding online public administration services (e-government).

In our view, *the smart city concept is a collective notion that combines various approaches*. Using the smart city criteria, we analyzed the relationship between the smart city concept and some other relevant concepts discussed above (Table 1).

Table 1 Relation of Smart City and paralel concepts

Relevant concept	Short definition	Smart City Criteria				
		1. High quality public services, living and working conditions for citizens and businesses	2. Involving as many citizens in the decision-making as possible	3. A conscious effort to use scientific and technological tools	4. Emphasis on the use of ICT as a key tool	5. Conscious consideration of environmental, social and economic sustainability, and minimizing vulnerability as a prime constraint
Green city	1. A city with many high-quality community green spaces 2. A city that prioritizes environmental sustainability and provides healthy living conditions	■				■
Creative city	A city where creativity is viewed as a key element of sustainable urban development	■	■			■
Digital city	A city that uses modern ICTs (IoT, AI, Cloud, Big Data, etc.)	■		■	■	
Intelligent city	It is often used as a synonym for smart city, while others mean a dynamic digital urban environment that can adapt to users and the environment beyond static buildings and urban infrastructure	■	■	■	■	

Source: edited by the authors based on Pongrácz (2020)

The intelligent city, most often used as a synonymous term, relies heavily on the use of ICTs. By using two-way communication, they also have the opportunity to involve their local community in urban decision-making processes, which became even stronger in the *e-democracy* approach later. The intelligent city aims to develop an efficient ICT-based system. However, *it does not directly address the issue of environmental sustainability.*

The other, frequently used synonym is *green city*. This approach focuses on creating a sustainable and livable environment. Its key focus areas are the provision of green spaces and a system of green areas in cities, and the use of renewable energies as much as possible in order to meet the city's energy needs. However, *the green city approach does not directly rely on ICT.*

We can conclude that, comparing the individual approaches with the definition of a Smart City we presented in this study, the notion of *the Smart City is*

the most general and integrative term and concept among the aforementioned urban visions. Based on our definition above, *this approach is the one that is suitable to offer solutions to the Smart City challenges addressed within SDG17*. An example to this approach is the Tungsram Smart City Action Plan.

3.3. Evolution of Smart City concept

Cohen distinguishes 3 generations of smart city process from the perspective of whether only large company recommendations are taken into account in the design phase, or whether there is a wide range of stakeholders involved when defining the goals or implementing the projects. These stages are the following (Cohen 2015):

- *Smart City 1.0 – Technology driven:* IT companies develop and offer smart solutions.
- *Smart City 2.0 – City driven:* Technology enablers utilized to improve of quality of life. Cities prepare Smart City strategies and action plans. Development decisions of smart solutions are based on these strategies.
- *Smart City 3.0 – Community driven:* Citizen co-creation of the concept. Citizens are not only beneficiaries of smart solutions but they are involved in the preparation process of strategy, and also offer smart solutions and locally used applications.

Nowadays a mixture of Smart City generations exists among cities in the world. For example, Sondgo and Masdar City belong to Smart City 1.0, Barcelona and Rio de Janeiro are rather under Smart City 2.0, Amsterdam and Vienna represent Smart City 3.0 (Gere–Czirják 2016). The Smart City Vision and Action Plan of Tungsram demonstrates the technology-driven stage of a Smart City.

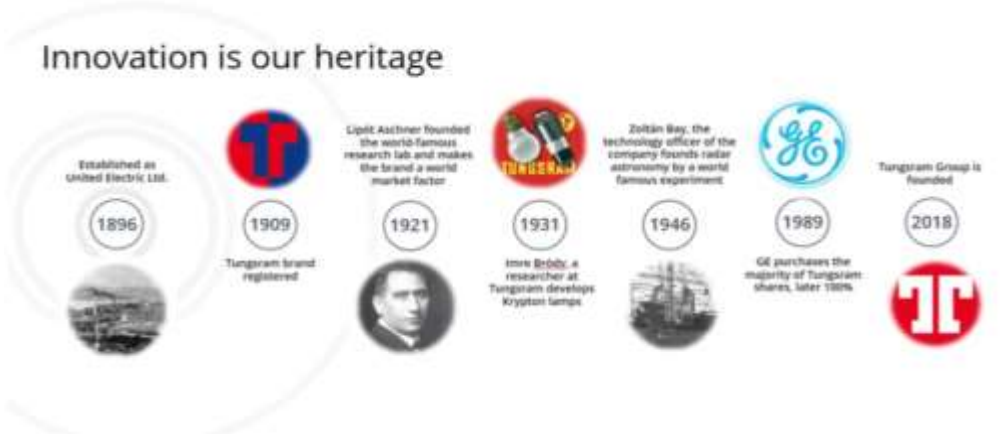
4. Tungsram's Smart City Vision and Action Plan[4]

Tungsram has a history of over 120 years. *Founded in 1896*, it was the first internationally recognized Hungarian brand (Figure 4). It has always aspired – and succeeded – to stay ahead of the curve: the company owned the first research lab in Europe in 1921, founded by the CEO *Lipót Aschner* at the time. Ten years later, in 1931, world-class researcher *Imre Bródy* invented, and received a patent for the krypton light bulb; and in 1946 *Zoltán Bay* laid the foundation of radar astronomy. *"Innovation is our heritage"* stands in the slogan of the company.[5] Tungsram has always had a *strong vision to foster leading technological inventions*. Today, Tungsram employs over 4000 people and has a presence in over 100+ countries.

[4] The inception and implementation of these elements of innovation are presented from a corporate point of view, based on the personal experience of one of the authors Ferenc Pongrácz, who is the General Manager of Innovation at Tungsram Group.

[5] https://tungsram.com/en/news/tungsram-innovation-is-our-heritage

Figure 4 A brief history of Tungsram



Source: Tungsram (Introductory presentation)

Tungsram's vision continues its rich heritage. In 2018, it established a separate Business Unit called *Tungsram Edge*, which has been made responsible for seeking out the most promising opportunities for innovation. Tungsram Edge's vision is, in line with many of the UN's SDGs, to provide smart and innovative physical and digital solutions for inhabitants of a city and for enterprises within or on the outskirts of a city to strengthen their environmental, social, and economic sustainability. While Tungsram itself does not own all the products and services, yet its major competitive advantage is that it acts as a technology integrator. Tungsram Edge, at the same time, operates on a *new business model*: it *matches demand with supply* as it aims to bring together all those startups and SMEs who have smart and innovative products *and has created a platform for cities and companies* who wish to take advantage of the synergies that an integrator – such as Tungsram – has to offer. The extensive use of ICTs, disruptive technologies, non-traditional business models, and the use of open innovation are all present in its mode of operation, as we have seen outlined in Figure 2.

4.1. Tungsram's Smart City Model

The key concept in Tugnsram's Smart City model is its human-centric design. As we have also quoted earlier from the UN's 2019 study, "populations are at the centre of sustainable development". Hence Tungsram's most important strategic imperative is to always keep *the people* in focus.

Tungsram highlights *three groups of stakeholders*: inhabitants, enterprises, and city management (Figure 5). In the definition of the stakeholders, we can discover the application and adaptation of the Triple Helix model of universities, industry, and government cooperation. While Tungsram does not name universities explicitly, the company has multiple agreements of cooperation with top Hungarian and international universities. Furthermore, Tungsram does not only limit the ground for innovation to universities, albeit they play a very significant role in the process, but it extends its reach to all "inhabitants", which is in line with the Open Innovation model.

Figure 5 Tungsram Smart City Model

Source: Tungsram (2019)

Tungsram has identified *ten focus areas* through which it aims *to contribute to the SDGs* through helping build and manage smart cities. While some were initially part of the company's core competencies, others are new in the portfolio and currently being developed. As an Action Plan, the company formed *Tungsram's Smart City portfolio*, and highlighted three distinct areas: *AgriTech*, *PropTech*, and *Smart Solutions* that are coming from Open Innovation based collaboration with 3rd parties.

4.2. Tungsram AgriTech

Tungsram brought into existence its AgriTech division in 2018. AgriTech targets the indoor farming or vertical farming needs that keep increasing along with the growing population worldwide that is concentrated in cities. The increasing scarcity of natural resources also contribute to the growth: 80% of arable land is already in use; 70% of all fresh water is used for food production while 65% of the water used is lost due to evaporation and runoff. At the same time, about 30% of fossil fuels are being consumed by food production.

On average, food often travels 2500 km or more to get from field to fork, while 50% of the crops that were planted are not harvested. Overall, about 14% of food is contaminated with pesticides while 0.1% of all pesticides used would actually reach the target.

Consumers become more and more aware of the health and environmental issues that food production is causing, and there is a change in demand around food production. People demand *shorter field to fork cycles to reduce CO2 emission*, and with a closer production facility, the *food will stay fresher and cheaper*, due to the *decrease*

of the transportation and refrigeration costs. While in 2011, around 1/3 of all food was lost or wasted every year, in 2019, the *UN's Food and Agriculture Organization* (FAO) estimates about 14% waste from harvest to retail. Despite a significant improvement since 2011, there is still a long way to go, especially that the target within the UN's SDGs is to half the per capita global food waste by 2030 (FAO 2019).

The increasing customer demand around organic products and the year-round availability of seasonal fruits and vegetables are also driving the need for more indoor farms, while exotic products for the medical and cosmetic industry are also increasingly sought after.

During the short time period since 2018 Tungsram become an internationally recognised premium quality producer of lighting products for indoor farms and developed its state-of-the-art vertical farming product portfolio.

Among Tungsram's most notable results, there are top international universities and research organizations that use its indoor farming lighting technologies for research and production, while Tungsram has also started its own vertical farm, and by now, even the UN's FAO recognizes it as a company "*responding creatively to crises with non-traditional farming".*

Research partnership with the University of Reading

The University of Reading, which is one of the most notable universities in the field of horticulture in *the United Kingdom*, has chosen *Tungsram's indoor farming lighting technologies to research strawberry production*. Their aim was to investigate growth, yield, and quality of strawberries lit by LED lights and compare them to the performance of plants under high pressure sodium lamps and unlit controls. The research toplights produced by Tungsram have been set to four different spectral distributions to investigate the results of different spectral compositions.

The results of the research, carried out August 2019, have shown that all four LED-lit compartments provided higher than average berry weights and a more compact fruit texture. In Class 1 of the experiment, the plants also produced a significantly higher yield. "In addition to better yield and higher crop quality, the most immediate benefit of using LED is to reduce the amount of power that is being used for plant cultivation. *The results of the experiment showed that energy consumption dropped by 40-50% in some cases*." explained Keith Thomas Tungsram AgriTech UK commercial leader (Thomas 2020).

Vertical farm developed in-house

Tungsram started its first hydroponic vertical farm in-house in 2020. A large factory building previously used to assemble lighting products has been turned into a world-class vertical farm home to various microgreens, such radish, garden cress, dill, lettuce, and other significant research plants such as chamomile, chilli, strawberry, and pak choy.

The shelves, divided into three levels, are being lit by 4-channel and 6-channel lightbars and can be controlled remotely. The light spectrums and their intensities can either be pre-programmed or changed real-time, just as researchers see a need to adjust

the spectral composition to best suit the plants' needs. There are various sensors monitoring the environment and sending data about the pH, the temperature, and the electrical conductivity of the hydroponic solution, as well as about the room temperature, the CO2 level, and the relative humidity. All lights, other hardware components just like the software itself, has been developed and manufactured by Tungsram.

The first results have shown an overall significant success. For certain plants, such as chili, Tungsram is still waiting for the laboratory results on capsaicin level, and chamomile is currently being evaluated for oil content. There are also some lessons the company learned about their integrated pest control strategies and will revisit those in the next coming trials.

In the next coming months, this in-house vertical farm will host, for the first time, a high wired plant nursery including tomatoes, peppers, and cucumbers.

Tungsram's strategy is to become an advocate and continue supporting indoor farming as a safe and sustainable food production methodology that saves energy, water, and pesticides providing various health benefits and being able to commercialize it as a "*plant as a service*" with well-established crop production strategies and consulting services to indoor farmers.

Food and Agricultural Organization recognizing Tungsram

Large urban operations, such as vertical farms are a great way to complement the urban food supply chain. *Precision indoor farming*, however, aims at serving a niche market, such as high-end restaurants or hotels. These closet-sized hydroponic cabinets create, establish, and maintain an ideal cultivating environment for select microgreens and offer an alternative smaller businesses or specialty kitchens.

In a recent article about *"Responding creatively to crises with non-traditional farming"* FAO recognized Tungsram as a notable company being able to respond well to the COVID-19 pandemic by quickly compacting its know-how about large vertical farm operations into a smaller-scale indoor farm that is more affordable for smaller businesses and individuals.

4.3. Tungsram PropTech

PropTech, or property technologies are the newest addition to Tungsram's business. *The reduction of property maintenance and utility consumption* tends to appear already in most municipality's strategic documents in Hungary and are the heart of sustainable development and smart cities. While the AgriTech division was primarily built on the core competence of lighting manufacturing, PropTech evolved from the need to make the buildings more efficient not only in the area of lighting, but in the *overall area of facility management*: smart buildings make up smart cities.

The lifecycle of a building consists of the design phase, the construction phase, and the operation and maintenance phase. While the design phase is only 1% of the overall costs, construction is about 9%, and the remaining 90% is spent during the operation and maintenance phase. There is an increasing need to use *computer aided facility management* (CAFM) systems in the operation and maintenance phase.

In the summer of 2019, Tungsram has acquired an IT company and it now owns a property and facility management and maintenance software called *ArchiFM*. With ArchiFM, facility managers can better automate asset, area, and tenant management, optimize maintenance and workflow management, and thus reduce the overall costs of a building's operation. The solution improves Energy efficiency and helps to reduce CO2 emission.

Puskás Arena

One of our most recent and most notable references in the field of efficient building management is Hungary's largest public building, the *Puskás Arena*. The 67,000-seat stadium's senior management carefully examined the possibilities and decided to entrust ArchiFM to integrate and manage their *Building Information Modeling* (BIM) models and their related systems. "Among our most important selection criteria when trying to find a service provider were that they have to be able to offer services locally while seamlessly adjusting to our facility management needs, that they have relevant references, and be experienced and dedicated to manage the BIM model of the largest public building in Hungary," explained Puskás Aréna manager Barnabás Mesics in Tungsram's reference video.

When setting up the system, ArchiFM thoroughly merged and consolidated all heating, ventilation, air conditioning, electricity, IT, and safety-related information and mapped all parameters from various sources that were used during the design of the building. It resulted in over 10GB of structured data that we imported into ArchiFM. After creating a comprehensive asset inventory, we implemented our facility management best practices to be able to optimize their workflow management.

After the implementation, we have been able to achieve success in

- Environmental efficiency, by being able to digitally control heating, ventilation, and air conditioning that matches occupancy and thus by reducing CO2 emissions
- Cost reduction, by using less electricity and a more efficient workflow management process
- Service quality improvement, by having a cleaner, safer, and more proactive environment for workers, athletes, and visitors

4.4. Open innovation Partnerships – Smart Solutions

Tungsram has been continuously collaborating with innovative Hungarian and international Small and Medium Businesses and Start-ups in order to create a comprehensive Smart City product portfolio that includes solutions provided by multiple players but can be seamlessly integrated and supported by an internationally recognised player. Smart Solutions product portfolio currently includes solutions for *indoor and outdoor positioning, smart parking, building automation, people counting cameras, ambient sensor network, workspace management*, and various *audiovisual solutions*. Tungsram has established, and keeps building, a remarkable partner ecosystem and constantly maintains and manages its product portfolio.

As one of our first achievements is a demo environment at the Budapest Headquarter placing ambient sensors in meeting rooms that are able to track data about the physical environment, such as room temperature, CO2, humidity. People counting sensors are able to monitor occupancy, which can be used to scale back heating / air conditioning or provide information about meeting room usage and frequency.

Outside, in the parking lot, sensors are installed complemented by a navigation system available through an app to guide one to the closest available parking spot.

By these actions, three objectives are achieved:

- Environmental efficiency, by reducing CO2 emissions through less energy (electricity of fuel) consumption
- Cost reduction, by also using less energy
- Service quality improvement, by having a pleasant meeting room to enter, or by not having to waste time trying to find a free parking spot when in rush to make it on time for a meeting

Each actions of Tungsram's Smart City porfolio may directly or indirectly contribute to the UN SDGs. Table 2 presents *indicative measures of the effects* of Tungsram's Smart City portfolio. The establishment of the AgriTech division within Tungsram directly addresses the following UN sustainable development goals: 2, 6, 7 and 12, and it indirectly contributes to 3, 8, 9, 11, 13 and 17. Indoor and vertical farming extend the capacity of food production in different climate conditions, use water and energy efficiently, reduce food losses along production and supply chain. It is also a manifestation of a human-centric design that addresses people's needs and demands in a sustainable and yet profitable manner.

Table 2 Relation of Tungsram's Smart City Portfolio to SDGs

Sustainable Development Goals	**Tungsram's Smart City portfolio**		
	AgriTech	**PropTech**	**Smart solutions**
SDG1: No Poverty		Indirect	
SDG2: Zero Hunger	Direct		
SDG3: Good Health and Well-Being	Indirect	Indirect	
SDG4: Quality Education			
SDG5: Gender Equality			
SDG6: Clean Water and Sanitation	Direct		
SDG7: Affordable and Clean Energy	Direct	Direct	Direct
SDG8: Decent Work and Economic Growth	Indirect		Indirect
SDG9: Industry, Innovation and Infrastructure	Indirect	Direct	Direct
SDG10: Reduced Inequalities			
SDG11: Sustainable Cities and Communities	Indirect	Direct	Indirect
SDG12: Responsible Consumption and Production	Direct	Indirect	
SDG13: Climate Action	Indirect	Direct	Indirect
SDG14: Life Below Water			
SDG15: Life on Land			
SDG16: Peace, Justice and Strong Institutions			
SDG17: Partnership for the Goals	Indirect	Indirect	Indirect

Direct contribution
Indirect contribution

Source: edited by the authors

With the establishment of the PropTech division, Tungsram directly addresses the following UN sustainable development goals: 7, 9, 11 and 13, and it indirectly contributes to 1, 3, 12 and 17. Efficient buildings increase the efficient resource use and have greater adoption of clean and environmentally sound technologies including renewable energies and focusing on improvement of energy efficiency. Additionally, proper facility management ensures safe, and affordable housing and basic services.

Tungsram Smart Solutions directly addresses the following UN sustainable development goals: 7 and 9; and it indirectly contributes to 8, 11, 13 and 17. The different smaller and larger scale solutions contribute to IT-based, adequate, safe, and efficient public and private basic services.

Some of the direct effects were quantified in the presented case studies (research partnership with University of Reading, vertical in-house farming, Puskás Aréna, ambient sensor network). Most projects of the Action Plan are under design or at the starting phase. That is why some other measures represent a subjective evaluation of the authors. Based on feasibility studies and/or monitoring of implemented projects, future studies may establish a methodology to elaborate exact quantification of the effects on SDGs by Tungsram's Smart City actions.

5. Conclusion

The accelerating speed of urbanization create sustainability challenges in all cities. The complexity and the severity of these challenges varies geographically. We have examined the circular driving forces that are happening in cities today and reviewed the UN's SDGs.

Nowadays, theSmart City concept is an integrative and a general future city vision. Smart City is featured by efficient use of ICTs, involvement of community, and environmental, social and economic sustainability. These characteristics ensure that a well thought through Smart City approach is indeed able to provide solutions to manage challenges described in the UN's SDG17.

In the empirical part of the paper, we have investigated the Smart City action plan of a Hungarian multinational company Tungsram and demonstrated how the business units that aim to make cities smarter evolved. Tungsram's strategy to promote a human-centric design helped create a healthy partner ecosystem, and it is a driving force to attract those businesses and business models that believe in the same concept. We have also seen that the product portfolios of the three divisions under Tungsram Edge are capable of significantly contributing to the UN's sustainability goals.

With the shift in demographics and the increasing need to act prevent climate change, we believe that any city and any company at their own capacity should use ICTs, innovation, and smart solutions of any kind to contribute to the SDGs of the United Nations.

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