**SMART CITIES DEVELOPMENT AND TRENDS:   
CASES AND RESEARCH OPPORTUNITIES**

Editors: Maja Ćukušić, Anton Manfreda and Mario Jadrić

**PREFACE**

The content of this book is intended to contribute to challenges of managing a smart city, technology acceptance issues and new underlying business models. The book provide theoretical and empirical underpinnings regarding the development and current trends of the smart city concept together with proposing future research opportunities.

Researchers agree that 5G technology and digital transformation is crucial for the development of smart cities and smart public administration. The concept of smart cities derives from the global trend of urbanization. According to United Nations Population Fund, the latest figures show that population share in the cities doubled in the last few years and is expected to reach over 70% of total population by the end of 2050. Consequently, cities need to cope with the related and the upcoming changes/challenges while cities branded as ‘smart’ need to keep or reach high standard of quality of life of their citizens. With the popularization of the smart city concept and through the implementation of the digital transformation projects in the public administration, information services are radically changed, heavily impacting systems in urban environment. In an effort to identify and explore the challenges, the potential and the priorities for the implementation of smart city applications cities often encounter problems that are complex, assuming considerable uncertainty.

Managing digitalization is becoming increasingly demanding due to rapidly evolving innovations and the difficulty of managing the complexity of related technologies. However, these issues are not challenging for organizations and individuals only, but also for cities and local communities. In particular, cities are faced with major challenges arising from global shifts in the environment, rapid urbanization and older infrastructure. As a result, several smart city-related initiatives are emerging. Yet, not all successful. The book is thus focus on the analysis of new business models, technological innovations and their use related to the development of smart cities. After all, the spread of technology and the availability of data automatically collected generate create new opportunities for managing public services and for the creation of new services.

The primary audience of this book will be students, academics interested in the smart city concept, government organizations, managers, policy makers, and strategic planners who intend to understand emerging digital technologies, their impact and applicability on cities. The book include strategies to implement and manage digital technologies together with the discussion on new business models. The Chapters in this Book are grouped in two parts – part one includes general theoretical and technical discussions of technologies and their benefits for modern cities and part two includes use cases of different digital technologies and business models.

**CONTENT**

**Part 1**

1. THE EMERGING WORLD OF SMART CITIES: DEFINITIONS, RESEARCH INITIATIVES AND WORLDWIDE EXAMPLES
2. ANTICIPATORY GOVERNANCE AND FORESIGHT: STATE OF THE ART AND IMPLICATIONS FOR URBAN DEVELOPMENT
3. MODELLING OF INTERNAL ORGANIZATION AND EXTERNAL CUSTOMER JOURNEYS IN SMART CITIES
4. ATTITUDE TOWARDS SMART CITY’S ELEMENTS – SELECTED TRENDS AND A COMPARATIVE STUDY BETWEEN DIFFERENT RESIDENTS

**Part 2**

1. CHALLENGES OF MANAGING A SMART CITY: ANALYSIS OF BUSINESS STUDENTS’ PERCEPTIONS
2. CRITERIA EVALUATION FOR SELECTING IOT PLATFORMS IN SMART CITIES: EVIDENCE FROM CROATIA AND SLOVENIA
3. DEVELOPING A CONCEPTUAL MODEL FOR SUSTAINABLE TRANSPORT INFRASTRUCTURE PLANNING: A SYSTEM THINKING APPROACH AND PRELIMINARY DYNAMIC MODELING
4. DETERMINANTS OF ACCEPTANCE AND USE OF THE PUBLIC BIKE-SHARING SYSTEM

**THE EMERGING WORLD OF SMART CITIES: DEFINITIONS, RESEARCH INITIATIVES AND WORLDWIDE EXAMPLES**

INTRODUCTION

This rapidly increasing urban population is bringing modern problems and affecting people’s life to a great extent. Fortunately, as the population grows and people migrate from rural to urban areas, technological advancement increases simultaneously and presents a potential way for facing with the issues. One of the potential solutions is also smart city development. The way smart cities are managed is through digitalization since intelligent solutions are based on integrated sensor technology, connectivity, data analysis gathered from these conectivity, and independent value-added processes. A digital transformation and connectivity are an essential part of a smart city as seen from the successful examples (Gassmann, Böhm, & Palmié, 2019).

There are different notions of smart cities such as, technological cities or digital cities and thus the primarily focus is on the technical side of development. However, there are also some downfalls of the technologically defined concept of a smart city. Incorporating and building technologies just for the reason of calling a city a smart, may cause overinvesting into technologies that do not improve citizens' life. Thus, the focus of smart cities should be also on a smart program or the ability to assist city planners and the municipal authorities, based on technology, to achieve higher efficiencies and performance on different frontiers (Sharifi, Allam, Feizizadeh, & Ghamari, 2021).

Transforming urban areas into successful, sustainable living settlements has been the goal of local authorities around the world for many years. Nowadays, there are a huge number of settlements or cities in the world that have decided to become so-called smart cities in order to achieve this goal of sustainability. Under the Smart Cities Program, many government organizations are currently working to help transforming cities, addressing well-being and sustainability, especially through high-tech solutions. Nevertheless, the notion of a smart city is ambiguous and the conceptual framework to help cities and their administrations understand the broader picture of this urban development paradigm is limited. In this chapter, we are thus presenting different smart city definitions, research directions and relevant underlying trends.

The aim of this chapter is to present the smart city trends in research and practice. Smart city definitions are presented at the beginning, followed by research trends on the topic across different research areas. Further on, various examples of smart city solutions and case studies from cities around the world are described.

DEFINING A SMART CITY

The concept of smart cities started appearing decades ago. Over the generations, the concept has been upgraded by introducing different innovations, which are currently being developed within the third generation. Emerging new or the fourth generation is working to make all elements of the city and its infrastructure (economy, transport, education, health, governance and other) "smarter". The development of the Internet of Things, integrated systems and their global integration is creating new opportunities to build smart cities and move to a “smart economy” based on Industry 4.0 including creating production that is harmless to the urban environment. Digital technologies create the conditions for horizontal integration that goes beyond “smart factories” and promote automated value chains at local, regional, national and global levels (Safiullin, Krasnyuk, & Kapelyuk, 2019).

Although the well-established definition of a smart city does not exist, experts do agree that it is a solution to many problems that occurred due to urbanization (Silva, Khan, & Han, 2018). Changes in the environment and the society force cities to rethink their infrastructure and governance. These changes arise mostly from the fact that people seem to move from smaller villages to greater cities (Dameri & Rosenthal-Sabroux, 2014). This urbanization trend can be seen all over the world, and it is expected to increase even further in the future (Laufs, Borrion, & Bradford, 2020). An increasing population within cities leads to a variety of problems. Examples are traffic, an increased pollution of the environment, higher energy consumption or how to deal with the increase in waste (Dameri & Rosenthal-Sabroux, 2014; Laufs, et al., 2020). The technological development in recent years allows for city governments to tackle these problems by using ICT (Laufs, et al., 2020). Naturally, as ICT enables the development of smart cities, most of the initial definitions of smart cities revolved around the usage of ICTs (Capdevila & Zarlenga, 2015; Laufs, et al., 2020). Over time, these initial definitions broadened towards a more holistic view, focusing on different aspects of a smart city. Besides the technological focus on ICT, smart cities were also based on the capabilities of the citizens (human resource focus), or the cities’ institutions’ governance and policy.

A smart city is one that puts people at the heart of development, incorporates information and communication technologies into urban governance, and uses these elements as tools to promote effective government formation that includes participatory planning and citizen participation. By promoting integrated and sustainable development, smart cities are becoming more innovative, competitive, attractive and resilient, thus improving lives (Bouskela, 2016).

Smart city developments have proved to be a favourite when looking for modern solutions to challenges we face with urbanisation. Because of the challenges posed by urbanisation, the need for smart city initiatives is rising. It is projected that by 2050 more than 66 per cent of the world population will be living in urban areas. As the migration to cities increases, the stress on the already existing infrastructure will increase. This stress in the long term might affect future sustainable development initiatives thus causing long term social issues, waste management issues and energy consumption issues. Cities which only take around 3 per cent of the entire landmass are using more than 75 per cent of global resources and supplies and account for more than 80 per cent of greenhouse emissions. Therefore, cities play a major role in social, economic and environmental issues so it is essential to collectively establish solutions to modernize cities leading them into a new era of sustainability and social development. Smart Cities have emerged to be a modern solution to old problems (Praharaj & Han, 2019).

In recent years research into Smart Cities has increased and the discussion on what constitutes a Smart City has attended the attention in the academic circles. Due to a vague definition of what a Smart city constitutes and how it should be implemented in our society, different terms are sometimes being used interchangeably. Terms such as digital city, smart community, sustainable city, intelligent city, information city, knowledge city, and tech city were all used in various applications to describe developments which could also be characterized by the term Smart Cities. These different definition aspects assert the notion that the term Smart City is a term which describes a broad array of different definitions and is somewhat of contemporary use of language describing urban development management. The term itself originates from the 1990s but has become popularized and recognized due to its usage by several companies, mostly originating from the technology sphere, such as Cisco, IBM and Siemens (Praharaj & Han, 2019).

Despite several different definitions there are commonalities which constitute a Smart City. Important characteristics a city must strive to become a Smart City are referring to (1) Information and communication technology or ICT; (2) Urban development led by businesses and entrepreneurs; (3) Community development and social capital; (4) Learning and knowledgebase development; and (5) Sustainability.

### Information and communication technology

In order to enable participation from stakeholders and manage large amounts of collected data Smart Cities are using ICT to process and analyse critical information. ICT enables the city to improve the reliability, quality, and performance of different urban services within a city. ICT is also crucial when it comes to reducing resource consumption and reducing different administrative and other costs. ICT works as a framework for many other Smart City applications, where they work atop the ICT system. Smart cities are also using ICT to improve the lives and interconnectedness between citizens and other stakeholders (Praharaj & Han, 2019).

Without the usage of ICT, a Smart City cannot exist. However, ICT cannot function alone and must be paired with intelligent city design which will further provide robustness, scalability and flexibility to the network. In order to improve these traits of a network, a city can follow several different network designs. It is essential for a smart city to design and build autonomous and simplified networks which can be managed by a single controller which reduces the complexity of the system and increases its efficiency. In order to further increase the robustness and flexibility of a Smart City’s network, a city should develop an automated threat detection that will deal with different issues as they arise. Internet of things is also an integral part of a smart city meaning ICT infrastructure should be designed to integrate different IoT applications seamlessly. Designers of ICT systems must keep in mind the scalability as cities will grow and focus on redundant systems which will increase the robustness (Allied Telesis).

This concept of “smartness” would not be possible without the rise of ICT, however, focusing only on the implementation of new technologies does not mean building a smart city. The utilization of those technologies should help accelerate standard operations in cities while positively impacting the life of its citizens (Silva, et al., 2018).

### Urban development led by businesses and entrepreneurs

A vital trait of a Smart City is their emphasis on business-led urban development which shapes its growth. In most smart cities the businesses and companies are included in the designing of a city or they can even be a crucial architect behind the developments. More and more cities are thus beings shaped by corporations. This ensures the connectedness between the citizens of such a city and different corporations as they are now both stakeholders with a vested interest (Praharaj & Han, 2019).

### Community development and social capital

Within a smart city, its citizens must learn to use ICT and other technologies learning to adapt to new innovations and integrate them into their lives. This will allow a community to use new technologies to advance living standards, improve existing systems and design various different applications of new technology in different fields. In order to allow for such integration, communities must strive to increase their social capital improving the relationship and connection between all residents (Praharaj & Han, 2019).

### Learning and knowledgebase development

Smart Cities foster a high demand for learning and innovation increasing the creativity of the residents. This allows for the existence of complex institutions of knowledge creation, knowledge management and infrastructure for communication (Praharaj & Han, 2019).

The infrastructure is the essential component that cannot be skipped. However, public institutions and policymakers often overlook the non-Internet technologies that could be used towards building a smart city. Additionally, an often skipped step is process mapping, and understanding all processes in the city, which is necessary for improving them (Baltac, 2019).

### Sustainability

Smart Cities invest in social development, infrastructure and ICT systems in such a way that they promote and allow for sustainable growth, increased quality of life and smart management of limited resources (Praharaj & Han, 2019).

SMART CITY RESEARCH – A BIBLIOMETRIC ANALYSIS

To better understand the state of research on the smart city concept a bibliometric analysis was conducted on the Web of Science data in May 2022. Further on, a co-occurrence analysis of author keywords was performed on articles from 2012 to 2021 to examine what are the main topics in smart city discussions across various research areas, namely 1. computer science and information systems, 2. engineering and 3. green, sustainable science, technology field.

The results show that the smart city topic has first occurred in 1991 but has not been studied extensively until the late 2010’s, specifically more than 80 per cent of the total number of publications until 2022 were published after the year 2017. The number of publications has been in decline since 2019 (see figure 1).

Chart, histogram

Description automatically generated

Figure 1: The number of publications on the smart city topic in the web of science database through the years

Most publications are either articles (48 %) or conference proceedings (42 %) (see figure 2), from the field of computer science, engineering, and telecommunications, published by IEEE, Springer Nature, and Elsevier. From that it is evident, that the most prominent disciplines covering the concept are technical, since the most research has been done on technological aspect of it. The vast number of conferences furthermore indicates on the attractiveness of the topic. The main centers of smart city research are China, USA, and India, from where the most authors are coming from.

Figure 2: A share of publications on smart city topic by type

The co-occurrence analysis was performed on author keywords on a sample of articles published in the years between 2012 and 2021, including 5.492 publications. The sample was further divided into three subsamples by research areas of interest, since the main objective of the analysis was to find the information on how research topics on the smart city concept varies across research areas. The first subsample included 1.282 articles from the WoS category “computer science, information systems”, the second one included 1.813 articles from the WoS category “engineering”, and the third one 535 articles from the WoS category “green, sustainable science, technology”. The mentioned categories were selected with the aim to get a more technological perspective together with sustainable fields perspective, since they are the main factors of the explored concept. For each sample, the co-occurrence analysis was performed excluding keywords “smart city” and “smart cities”, since they are related to all the other keywords.

## Computer science and information systems

Diagram

Description automatically generated

Figure 3: Keyword co-occurrence network of smart city research in computer science and information systems

Figure 3 indicates that the smart city research topics in computer science and information systems can be divided into five clusters differentiated by a different color (yellow, purple, blue, green, and red) with the keywords within clusters of the same colour having great similarities. The yellow cluster focuses on security and safety of blockchain technology, and internet of things (IoT). The blue cluster focuses on energy management and computing in IoT. The green cluster focuses on data analytics on big data. The purple cluster focuses on edge computing and computer architecture. And the red cluster focuses on the use of 5G, sensors and routing for data collection and optimization.

## Engineering

**Diagram, schematic

Description automatically generated**

Figure 4: Keyword co-occurrence network of smart city research in engineering

Figure 4 indicates that the smart city research topics in engineering can also be divided into five clusters (yellow, purple, blue, green, and red). The yellow cluster focuses on cloud and edge computing allowing for interoperability and monitoring. The blue cluster focuses on security and privacy of blockchain 5G technology. The green cluster focuses on machine learning, deep learning, artificial intelligence (AI), together with sustainability. The purple cluster focuses on big data analysis and fog computing. And the red cluster focuses mainly on the use of sensors and energy management in IoT.

## Green and sustainable science technology

A picture containing diagram

Description automatically generated

Figure 5: Keyword co-occurrence network of smart city research in green, sustainable science technology

Figure 5 indicates that the smart city research topics in green, sustainable science can be divided into nine clusters (yellow, purple, light blue, dark blue, pink, red, orange, brown, and green). The yellow cluster focuses on blockchain technology and deep learning use for achieving sustainability and resilience of cities. The light blue cluster focuses on urban planning related to machine learning and information communication technology (ICT). The dark blue cluster focuses on IoT, big data, AI, machine learning, cloud computing etc. related to pollution. The green cluster gives all focus on sustainability in smart cities related to climate change and technology. The purple cluster focuses on the governance of urban development related to renewable energy and smart grid. The red cluster focuses on the sustainable development, government and sharing economy, similarly to the green cluster. The pink cluster focuses on city initiatives related to smart mobility and transportation. The brown cluster focuses on energy efficiency related to IoT. And the orange cluster focuses on smart governance, mobility, and quality of life.

CURRENT SMART CITY RELATED TRENDS

Cities are currently experiencing revolutions in terms of planning and what defines a good life for their residents. There are several trends which are crucial to understanding what direction city planning will take. Each city will have its own unique circumstances and technicalities so now every trend can be utilized in every city. Different literature identifies different trends which cities might start implementing in the future or are already active. Some of the most important and most commonly identified trends are briefly described below.

## Green Planning of Cities

Heavily populated areas are usually defined by construction and high population density. Green cities are now pushing green planning as an alternative. This will increase the amount of green public space, increase the quality of life of the residents and will help heal the environmental impact of the city. We can observe a good case if we look at Singapore where they have completely transformed their city by planting trees, resulting in cleaner air. Such spaces will also encourage outdoor activities amongst residents such as cycling, walking and other types of sports. We can also observe that such spaces increase the connection to nature and allow families to enjoy the outdoors and parks, instead of spending their time at home. This type of planning also promotes the decrease of car-centric streets, which many cities, especially in Europe are moving away from (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014).

## Smart Health Communities

Cities are currently developing new types of healthcare systems which not only focus on immediate care but also on prevention and post-care. It is essential that cities move toward prevention as this would greatly reduce the burden on medical facilities. Both mentally and physically prevention is key to managing the well-being of residents. Better care facilities ensure that patients get the best care and to complete the cycle cities must invest in post-care in order to transition residents back to their normal life as soon as possible and ensure their wellbeing in the long term. Cities are also teaming up with technology companies to develop health warning systems and management systems allowing for better tracking of patient files (De Marco & Mangano, 2021).

## 15-minute Concept

Many cities today are moving to a concept called the 15-minute city. With this design philosophy in mind, neighbourhoods are being designed so that amenities and different services are all within a 15-minute range and accessible either by foot, bike or integrated public transport. This concept is better suited for bigger more dense cities, particularly in Europe where many cities already implement this approach (Antunes, Barocca, & Guerreiro Oliveira, 2021).

## Clean Mobility

One of the first changes that came in the early 2000 was the introduction of smart maps that gives the opportunity to monitor the condition of the roads in real-time, enabling the users to manage their own journey and avoid traffic. This change stimulates a more efficient and sustainable mobility system and decreases challenges that the previous condition of the roads: pollution, noise, congestion, and inefficient mobility infrastructure (Lyons, 2018).

Many cities today are working towards providing their citizens with clean, intelligent, and autonomous mobility through more walking and cycling spaces and where transport is provided as a service. Cities are striving to eliminate the need to travel. Within the concept of clean mobility, electrification plays a key role in this vehicle sharing. Combining these two cities eliminate congestion and pollution and can subsequently focus on intelligent mobility, where data plays a pivotal role (De Marco & Mangano, 2021).

## Inclusive Services and Planning

Cities are increasingly providing inclusive services, battling inequality by providing support for the most vulnerable members of society. Cities must ensure equal opportunities and equal participation in society in order not to exclude pieces of the populace and allow them the opportunity of a job and become interconnected (De Marco & Mangano, 2021).

As companies are becoming customer-oriented, they start to prefer services that are easier for the customers to use. The “as-a-service” concept is not new, but the terms Mobility-as-a-Service (MaaS) and Energy Efficiency-as-a-Service (EEaaS) are coined recently and offer lots of potential in the transport of people and goods, and cost-efficiency in emissions reduction (Crowe, 2022).

## Digital Innovation System

Systems like these allow cities to attract new talent, which will enable greater productivity, and creativity and will strive toward new innovations. By fostering an open culture and creating an ecosystem of universities, companies, government and the public cities will enable connections between the innovators and allow them to tackle the city's most profound problems (Antunes, et al., 2021).

## Circular economy

More and more cities are adopting new policies which foster the culture of a circular economy allowing for the fair trade of resources, focusing on sharing and reusing resources. Such an economy also limits waste and focuses on local production facilities such as farming (Antunes, et al., 2021).

## Smart and Sustainable Infrastructure and Buildings

In order to improve the use of energy, many cities have introduced the concept of the smart grid, which is an eco-friendly system and reduces the use of electrical resources. The system is based on two-way digital communication, where data about consumption is collected, monitored, and analysed in order to improve the use of energy, which results in higher transparency, efficiency, and lower costs (Tuballa & Abundo, 2016).

Cities are setting themselves goals of building sustainable structures, limiting the loss of energy and the usage of drinkable water which is becoming more and more scarce. Waste is also a big consideration, and building proper infrastructure for disposal and recycling is key to achieving a net positive in terms of sustainability. The Net Zero Carbon Buildings Commitment was signed by 28 signatory cities and is aimed to reduce carbon emissions caused in the building sector (Antunes, et al., 2021).

Utilizing the power of wind and other natural resources are already familiar ways of investing in clean energy to which most of the developed countries are dedicated to. However, cities are starting to use technology in an even more efficient manner, like to monitor energy use in real-time and to optimize energy consumption. The focus here is to use sustainable and ethical materials, companies are committed to being socially responsible and environmentally friendly. Moreover, cities are using the resources in most efficient way, mostly relying on renewable resources for energy.

3

## Public Participation in City Building

Cities are pushing to include their residents in more and more city decisions, giving them a sense of belonging and increasing the feeling of co-ownership. Through technology and open data, cities can ask residents to provide more information on what bothers them in the city and what might be changed. This gives cities a rough idea of the direction the residents want the city to move. A good example of this is the city of Leuven in Belgium where the authorities have already implemented a framework to collect citizen ideas on how to improve the city (Antunes, et al., 2021).

## AI Operations

Automated technology is truly the driver for the future. Cities have begun to recognize this trend and are moving to implement such technologies in many of their systems. Services such as transport, public safety and infrastructure are being upgraded with the help of automation. Cities are implementing central systems which control many aspects of the city removing the need for planning by human controllers but the system is instead controlled by AI technologies. A good example of a city which is trying to implement such a system is Cascais in Portugal where they have developed a managed command centre (Neirotti, et al., 2014).

## Cybersecurity and Privacy

At this time, cybersecurity is becoming more and more important. Cities manage enormous amounts of data which must be kept safe. It is essential that preventative measures be developed which protect these data vaults. Thus cities are investing more and more into security. As cities digitalize more and more systems become digital, meaning a cyberattack could also disrupt infrastructure and basic utilities. Citizens of such cities are being taught the value of data privacy and cities must think carefully when managing sensitive data. A good example of a city following this trend is Tel Aviv where due to an increasing number of cyberattacks they have started to develop more and more advanced countermeasures (Neirotti, et al., 2014).

More ransomware attacks are also expected to happen on a global level. Immense pressure will be put on governments to build resilient cyber systems to have a strong defence against any cyber-attacks. The focus should thus be on data protection, frequent system backups, building cyber contingency plans, and cybersecurity education (Musulin, Teale, & Crowe, 2021).

## Surveillance and Policing Through AI

Cities are using the power of AI to ensure the security, safety and wellbeing of their citizens and all the while safeguarding their privacy and human rights. The upside of this technology is that it can prevent many crimes and also help detain offenders after a crime has been committed. However, this trend is still very controversial as it can be seen as an invasion of privacy. Such AI’s are able to accurately predict if a person has committed multiple crimes by comparing data from different crimes. Such controversial systems can already be seen today, especially in China, where the government is using AI systems to monitor their citizens (Antunes, et al., 2021).

CASES OF SMART CITY IMPLEMENTATION

## Dubai

Dubai’s mission was to improve the quality of life and increase happiness of its residents and visitors with a rapid adoption of digital innovation to make the city more sustainable, inclusive and safer as well as enhance people’s experience in it (Dassani, Nirwan, & Hariharan, 2015). A big reason for Dubai’s success in the transition into a smart city has been a high and increasing dependence of its population on their personal devices. A challenge is concerned with privacy since there is a necessity for cities’ creation of privacy governance policies that clearly state which data can be collected and stored and who can have access to it (Dassani, et al., 2015).

Dubai has its own office for digital transformation, namely Digital Dubai (Digital Dubai, 2020). More than 130 projects and partnerships with governmental and non-governmental organizations have been launched within this office. Their key initiatives include a data initiative, a blockchain strategy, a happiness agenda, an artificial intelligence plan, a start-up assistance and a paperless strategy. Below, the data initiative and a start-up assistance is additionally described.

The main purpose of the Data Initiative is to increase the smooth accessibility and exchange of location data, improve data management and coherence, and establish a strong data community. Data is used for (1) measuring the social happiness index with the help of AI; (2) visualization of electricity and water consumption in urban communities; (3) a food inspection dashboard to help inspectors plan inspection locations, frequencies and results with a visual display; (4) observing urban flow as the population changes and moves, which is invaluable for urban planners, government entities and real estate developers.

Eventually, Dubai Data wants to become an impartial market data intermediary in the city and create an open and well-regulated market where the value of data is realized and used to trigger new opportunities.

A start-up assistance refers to Dubai Smart City Accelerator which is a leading accelerator supporting innovative businesses in areas of the Internet of Things and Connectivity, Urban Automation, Mobility, Artificial Intelligence, Sustainable Cities, Smart Government and the Smart Retail Industry. With the initiative the focus is on looking for innovative solutions to help make cities smarter and overcome important challenges due to congestion, waste and energy to improve people's quality of life.

The initiative Digital Dubai is implemented through a large number of technology-supported applications that residents and visitors to the city can use on a daily basis to make life easier and better. These include Dubai Now, Rashid, Dubai Pulse, Dubai Careers, Smart Employee, Happiness Meter and many more.

For example Dubai Now is government application to provide access to 120 public and private sector services. The goal is to offer everything in one place such as: (1) payment of bills; (2) everything related to driving (payment of parking fees, fines, renewal of driver's license, car registration, sale and purchase of cars, car insurance, up-to-date traffic data ...); (3) housing related activities (payment of bills for water and electricity, data on water and electricity consumption, viewing of real estate, ordering services for the home, visa arrangement…); (4) health (viewing and managing medical examinations, results and prescriptions for medicines, finding doctors ...); (5) education (offer of all schools, signing of a contract between parents and school ...); (6) security (requesting police certificates, searching for the nearest station, checking the status of cases in court...); (7) travel (flight information, lost and found…); (8) Islam (daily prayers, mosques nearby...); and more (like donations, calendar of events in Dubai...).

## Amsterdam

Amsterdam's smart city path begins in 2009 when the city of Amsterdam launched a program called “Amsterdam Smart City” with the goal of reducing CO2 emissions by 40% by the year 2025 (Danielou, 2014). The Amsterdam Smart City program is an open community platform with which Amsterdam aims to connect and bring together all of the different stakeholders so that they can more easily share their knowledge, expertise, ideas and projects (Deskos). In the beginning, the Amsterdam smart city project covered five areas on which its incentives would focus, yet over the years it expanded the list to 8 categories. These categories are big and open data, smart society, smart mobility, smart living, smart areas, smart economy, living labs and infrastructure (Brokaw, 2016). The Amsterdam Smart City program works as a kind of catalyst, where it gathers projects and ideas and helps the better ones grow faster and bigger. Over the years it has launched several hundred projects of which many of them could theoretically be replicated and implemented in other cities around the globe. The program's success exceeded all expectations with Amsterdam winning the title of Europe’s Capital of Innovation award granted by the European Commission in 2016 (Deskos).

One of the more famous projects started by the Amsterdam Smart City platform is the so-called “Climate Street” or “Klimaatstraat”. With this project, Amsterdam aims to be part of the very top sustainable cities by 2040. In this street 40 entrepreneurs work on different solutions and fixes on how to reduce CO2 and NO2 commissions in their street, like smart lights, smart cooling and heating systems and other solutions. These solutions will then later be transformed and implemented to fit cities all across the Netherlands and not just Amsterdam (Veen, 2016).

Amsterdam has definitely solidified its position not only as a Smart City but also as a leader in terms of innovation in the field of smart cities, with the move to make all its City data open-source, meaning everyone could access it and add onto it to improve it even further, using smart meters to remotely regulate house energy consumption in real-time, the countless improvements to support public transport, electric vehicles, but also strengthen the already existing biking culture in Amsterdam and the Netherlands, new sources of renewable energy production and many others (Brokaw, 2016; Danielou, 2014; Deskos).

With the fast population growth and the numerous tourists, the city can get very crowded and unsafe. Public Eye project is a smart city design using Artificial Intelligence and city cameras to monitor crowds in public places. It can predict the size, density and speed of crowds and send staff to intervene if a risky situation is presented. During the pandemic, The Public Eye was also used for measuring the social distancing between people. Traffic lights were positioned outside facilities to let people know when they are full, and LED stripes were used to keep people at the recommended distance in public areas. As for the privacy concerns, the developers have stated that the camera footage is not being saved nor recorded, and the system is open source, meaning that anyone has access to it and can analyse the algorithm behind it. The reason for its placement is stated under every camera (Wray, 2021).

## Barcelona

Back in the 1990s, Barcelona developed and presented a Smart City Strategic Plan, which was intended to make the city the leading smart city in Europe. Barcelona was suffering from enormous infrastructural problems due to the high level of urbanization, dense construction in the city and, at the same time, weak urban planning. Additionally, there have been multiple economic crises in the region during that time and Barcelona was preparing to host the Olympic Games in 1992. Therefore, a city's strategic plan and smart city initiatives were more than necessary. It was intended to address and improve the previously poor planning in terms of housing, environmental issues, water, transportation and energy (Bakıcı, Almirall, & Wareham, 2013).

Like many other smart cities around the world, Barcelona invested heavily in ICT infrastructure and IoT networks, especially in the early 2010s. Through the new technological infrastructure Barcelona created citywide sensor networks that collect data on energy, environment, transport and so on, to provide instant feedback e.g. on air quality, waste management, noise, public transport options, parking spots etc (Bibri & Krogstie, 2020). The aim of the democratization of Barcelona’s ICT infrastructure is to provide opportunities for citizens to test and try out the technologies and to get feedback on what is useful and what might be a failure for urban development. When citizens are more technologically literate they better understand how and when technologies can be useful (Urban Hub, 2018).

But what makes Barcelona’s Smart City initiatives distinct is the so-called Smart City 3.0 approach which is mainly about the strong inclusion and participation of its residents. In 2015 the city of Barcelona re-focused from a top-down style towards a more citizen-centric approach. In doing so, Barcelona has taken different actions. First, a new data infrastructure has been developed, consisting of three components: Sentilo, an open-source-based data collection and sensor platform, CityOS, another open-source platform for analysing data, and various service apps at the UI level that facilitate access to all data. Second, this integrated control serves to democratize data. For example, the new platform and all the data it contains belong to the city. It can be used by citizens, private companies and other interested parties; however, the city and residents remain the true owners and decide on access and privacy (Smith, 2018).

Thus it seems that Barcelona’s smart city approach is really citizen-centric already in its core. Instead of just transforming the city in a top-down manner, the government aims to integrate its inhabitants into the transformation process and simultaneously prepares them for the challenges and opportunities of the 21st century, thereby acknowledging that a smart city can only develop out of both directions: top-down and bottom-up, and that it is not viable without its smart citizens. Social inclusion is thus the focus of Barcelona’s approach (Noori, Hoppe, & de Jong, 2020).

There is a smart waste collection system in place in Barcelona. The system works with the help of the special ultrasonic sensors which are placed within and show to which degree the bins are full. Consequently, sanitation workers can plan their routes by the sensors; they can empty the full bins first and the ones that are on the way. This reduces time spent on collecting the waste, which additionally decreases the fuel costs. Some bins are also directly connected to the underground repositories; enabling the waste is being vacuumed out by underground pipes and incinerated. The energy that comes from this waste incineration is further used for the city’s heating system (Bibri & Krogstie, 2020).

## Helsinki

Helsinki over the years has shown commitment to fighting climate change through building smart energy solutions. The smart buildings system has been a good example of a collaboration between cities and businesses toward creating a more functional and climate-neutral environment for citizens. Smart buildings systems can recognize where energy is wasted and how it can be saved, which noticeably increases the energy efficiency of buildings. The city is promoting its strategy to local businesses and building a supportive environment that can enhance collaboration. Opening data to public use must be seen as a benefit for all stakeholders, and not as a governmental control tool. Thus, security related issues must be thoroughly considered. The city thus supports the goal that all smart solutions must be developed in respect to security and privacy concerns of all stakeholders in the city. It is achieved through many consultations of city lawyers with different city organizations (Hämäläinen, 2020).

The Helsinki model includes open data, interfaces, innovation, ecosystem and public-private cooperation. Most of the operators and transportation companies have allowed access to their data. Helsinki Region Transport (HSL) as a local public transportation authority has opened all the relevant data about the routing, maps, timetables and vehicle locations that can be used by everyone. Besides the fact that Helsinki was ranked the leading city in the implementation of MaaS in Juniper Research’s 2018 study, it is highly ranked on the lists for air quality, congestion, bicycle use, mass transit use and cost of single city public transport tickets as well. The ambitious target and vision of Helsinki Regional Transport is public transport to be the number one choice for travel. The plan by 2025 is that 30% of the buses should be running on electricity which would be generated in a sustainable manner for example using a wind, hydro or solar. In order to complete that vision, the city set some goals like Smooth journeys, Clear services, Increasing public transport use, Compact and attractive regions, Fewer emissions and Effective finances.

## Copenhagen

Copenhagen aimed to lead the change in the city’s carbon emissions and energy consumption, through the intelligent solutions in waste disposal, lighting and air quality (Tomás, 2017). The key smart city initiative for Copenhagen was the Danish Outdoor Lighting Lab. The initial aim of the lab was to test the LED solutions for energy efficiency. But eventually, it comprised other smart city solutions in the field of mobility and parking, environmental monitoring, waste management, Internet of Things communication systems and many more (Hansen, 2020). The technology collects the data throughout the whole city and makes a connection within its infrastructure, and therefore it helps the municipality monitor and optimize smart city solutions in real-time to meet the citizens’ needs. The living lab enabled the city to start with its plan to reduce carbon emissions and energy consumption. The municipality had to monitor the emissions and their sources, and they used the lab’s data to do this.

In 2009, the municipality decided to start with a plan to become a carbon-neutral city by the year 2025. This means not only reducing and finally eliminating emissions within the city of Copenhagen, but also outside its geographical boundary (Damsø, Kjær, & Christensen, 2017). The energy sector contributes the most to the emissions, but it also has the largest share of initiatives and impact in the climate action plans (CAP). The first CAP focused on improving the district heating system and promoted the wind power expansion. Artificial intelligence is used to predict when and how much heat and ventilation the municipality buildings will need. CAP also promoted alternatives to using fuel in transport, switching from coal to biomass. The city set up electric chargers and established natural gas and a hydrogen gas station, and started switching to alternative fuels in the entire municipality fleet.

The city also collaborated with Google to start measuring the air pollution down to the street levels in the project called Air View. The Google Street View car, equipped with air quality measuring equipment, built a precise map of air quality along with Copenhagen blocks. It showed that the main roads have on average multiple times higher ultrafine particle concentration in the air than the residential areas with less traffic. The city is now using this data to design future neighbourhoods in a way to keep schools and playgrounds, as well as bicycle and walking routes away from highly polluted roads. It will also enable to use the data to foster more sustainable transportation (Utrecht University, 2021). For the same reasons, the city of Copenhagen established five measuring stations around the city in areas characterized by heavy traffic and stoves.

In the terms of waste management and utilization, Denmark has been a front-runner in diverting municipal waste from landfill, and its waste management system is almost completely designed around burning waste for energy. Therefore, the city of Copenhagen introduced some new initiatives to increase plastic collection and separation to remove fossil fuel-based waste from incineration. They gave the opportunity to each household to sort out the hard plastics from their waste (Damsø, et al., 2017).

Several initiatives were also introduced to help prevent food waste. The city opened social supermarkets, the shops that sell the food surpluses and goods that can no longer be sold because of overdue ‘best before’ dates, incorrect labels, or damaged packaging due to different reasons, but the food in these markets is still edible and safe to use. Consequently, they introduced the social supermarkets’ application for mobile phones named “Too Good To Go” in 2016. The app connects its users with local stores, restaurants and bakeries in their area that are selling their food surpluses at reduced prices (Ghafoor, 2021).

CONCLUSION

The share of the urban population in relation to rural areas has been rapidly increasing in the past decades and will further increase. Most of the population is already living in urban environments, causing various issues. Cities are using digitalization as a tool for effective and efficient planning, managing, and governing by implementing smart initiatives. Moreover, they are taking into account international and national policies, adapted to the local context. In the past decade, there has been a tremendous growth of interest in the international research community on complex urban questions, arising from the challenges that come hand in hand with urbanization. New disciplines emerged, exploring the innovative approaches to overcoming the mentioned challenges by the implementation of smart initiatives. The smart city concept has been born, alongside concepts like sustainable or green city, as a new managerial approach. The understanding of the smart city concept was first limited to the digitalization of city processes but has in recent years pointed out the importance of sustainability with the aim of providing a good quality of life for its residents. The new perspective put the responsibility on cities to help solve the environmental crisis happening worldwide, since they are one of the biggest producers of harmful greenhouse gases, together with agricultural activities and forestry. To conclude, even though smart cities have been extensively researched in recent years, there are still many perspectives, that have not been covered yet. Moreover, case studies show that there are many challenges remaining in practice as well, which brings numerous possibilities for further research of the concept.

REFERENCES

1. Allied Telesis. ICT: The Fundamental Enabler for Smart Cities, from <https://www.alliedtelesis.com/si/en/blog/ict-fundamental-enabler-smart-cities>
2. Antunes, M., Barocca, G., Guerreiro Oliveira, D. (2021). Urban future with a purpose: 12 trends shaping human living: Deloitte University.
3. Bakıcı, T., Almirall, E., Wareham, J. (2013). A smart city initiative: the case of Barcelona. *Journal of the knowledge economy*, 4(2), pp. 135-148.
4. Baltac, V. (2019). Smart cities—A view of societal aspects. *Smart Cities*, 2(4), pp. 538-548.
5. Bibri, S. E., Krogstie, J. (2020). The emerging data–driven Smart City and its innovative applied solutions for sustainability: The cases of London and Barcelona. *Energy Informatics*, 3(1), pp. 1-42.
6. Bouskela, M. (2016). The Road toward Smart Cities, Migrating from Traditional City Management to the Smart City, Inter-American Development Bank (IDB).
7. Brokaw, L. (2016). Six Lessons From Amsterdam’s Smart City Initiative. *Sloan Review*.
8. Capdevila, I., Zarlenga, M. I. (2015). Smart city or smart citizens? The Barcelona case. *Journal of Strategy and Management*.
9. Clark, W. W. II., Cooke, Grant. (2020). *Smart green cities: toward a carbon neutral world*. Routledge.
10. Cró, I., Roegiers, T. (2021). Data protection in the smart city of Lisbon. Lisbon: Flanders Investment & Trade.
11. Crowe, C. (2022). 12 predictions about the trends that will shape smart cities in 2022. *Smart Cities Dive*.
12. Dameri, R. P., Rosenthal-Sabroux, C. (2014). Smart city and value creation. *Smart city* (pp. 1-12): Springer.
13. Damsø, T., Kjær, T., Christensen, T. B. (2017). Implementation of local climate action plans: Copenhagen–Towards a carbon-neutral capital. *Journal of cleaner production*, 167, pp. 406-415.
14. Danielou, J. (2014). Smart city and sustainable city : the case of Amsterdam. Available at: <https://www.citego.org/bdf_fiche-document-2429_en.html>
15. Dassani, N., Nirwan, D., Hariharan, G. (2015). Dubai A New Paradigm For Smart Cities. UAE: KPMG.
16. De Marco, A., Mangano, G. (2021). Evolutionary trends in smart city initiatives. *Sustainable Futures*, 3, 100052.
17. Deskos, N. How Amsterdam Smart City aims to shape the city of the future. Available at: <https://crowded.co/blog/case-studies/amsterdam-smart-city>
18. Digital Dubai. (2020). Our vision is to digitalize life in Dubai, from <https://www.digitaldubai.ae/>
19. Gassmann, O., Böhm, J., Palmié, M. (2019). *Smart cities: Introducing digital innovation to cities*: Emerald Group Publishing.
20. Ghafoor, A. (2021). The Best Ways to Reduce Food Waste in Denmark, from <https://www.scandinaviastandard.com/the-best-ways-to-reduce-food-waste-in-denmark/>
21. Hämäläinen, M. (2020). A framework for a Smart City design: digital transformation in the Helsinki Smart City. *Entrepreneurship and the Community* (pp. 63-86): Springer.
22. Hansen, M. P. (2020). Collaborating in Europe’s leading living lab for Smart City-services: the case of Danish Outdoor Lighting Living Lab.
23. Laufs, J., Borrion, H., Bradford, B. (2020). Security and the smart city: A systematic review. *Sustainable cities and society*, 55, 102023.
24. Lyons, G. (2018). Getting smart about urban mobility–aligning the paradigms of smart and sustainable. *Transportation Research Part A: Policy and Practice*, 115, pp. 4-14.
25. Musulin, K., Teale, C., Crowe, C. (2021). CES showcases 6 trends to shape smart cities in 2021. *Smart Cities Dive*.
26. Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. *Cities*, 38, pp. 25-36.
27. Noori, N., Hoppe, T., de Jong, M. (2020). Classifying pathways for Smart City development: comparing design, governance and implementation in Amsterdam, Barcelona, Dubai, and Abu Dhabi. *Sustainability*, 12(10), 4030.
28. Praharaj, S., Han, H. (2019). Cutting through the clutter of smart city definitions: A reading into the smart city perceptions in India. *City, Culture and Society*, 18, 100289.
29. Safiullin, A., Krasnyuk, L., Kapelyuk, Z. (2019). *Integration of Industry 4.0 technologies for “smart cities” development*. Paper presented at the IOP conference series: materials science and engineering.
30. Sharifi, A., Allam, Z., Feizizadeh, B., Ghamari, H. (2021). Three decades of research on smart cities: Mapping knowledge structure and trends. *Sustainability*, 13(13), 7140.
31. Silva, B. N., Khan, M., Han, K. (2018). Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustainable Cities and Society*, 38, pp. 697-713.
32. Smart Geneva. Innovating together for a sustainable territory, from <https://www.smart-geneva.ch/en/home>
33. Smith, L. (2018). Smart City Portrait: Barcelona. Available at: <https://hub.beesmart.city/city-portraits/smart-city-portrait-barcelona>
34. Tomás, J. P. (2017). Smart city case study: Copenhagen takes on waste, lighting, air quality. Available at: <https://enterpriseiotinsights.com/20170420/smart-cities/smart-city-case-study-copenhagen-tag23-tag99>
35. Tuballa, M. L., Abundo, M. L. (2016). A review of the development of Smart Grid technologies. *Renewable and Sustainable Energy Reviews*, 59, pp. 710-725.
36. United Nations. (2020). World Cities Report 2020: The value of sustainable urbanization.
37. Urban Hub. (2018). Smart city 3.0 – Ask Barcelona about the next generation of smart cities. Available at: <https://www.urban-hub.com/cities/smart-city-3-0-ask-barcelona-about-the-next-generation-of-smart-cities/>
38. Utrecht University. (2021). Project Air View measurements result in hyperlocal map of air quality in Copenhagen, from <https://www.uu.nl/en/news/project-air-view-measurements-result-in-hyperlocal-map-of-air-quality-in-copenhagen>
39. Veen, E. (2016). Climate street (Klimaatstraat). Amsterdam Smart City, from <https://amsterdamsmartcity.com/updates/project/climate-street>
40. Wray, S. (2021). Why the City of Amsterdam developed its own crowd monitoring technology: Cities Today.

**Anticipatory Governance and Foresight: State of the Art and Implications for Urban Development**

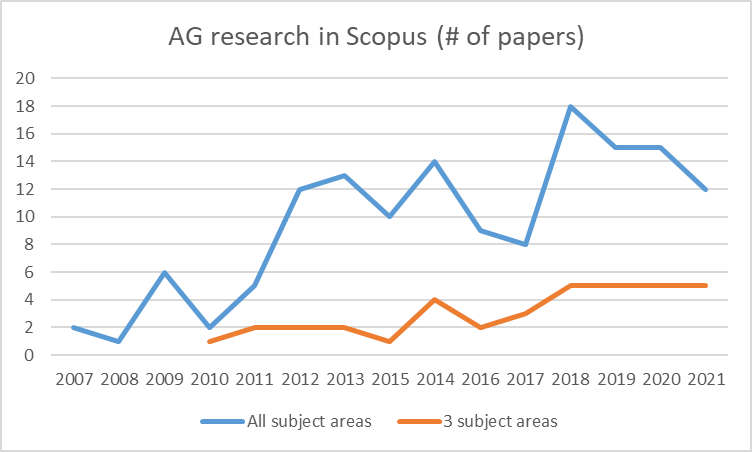
Introduction

In today’s world, the only continuous thing is **change**. The changes can happen slowly over a certain period of time, but can happen rapidly and unpredictably; their speed of occurrence, intensity, predictability and effects may vary significantly on all levels including local and global ones, in governmental and corporate environments. Governments and governmental institutions identified a need to prepare for future changes that bring threats and opportunities (Ramos, 2017), and for this reason, they increasingly started to (re)consider the future in their policy- and decision-making.

Focusing on the cities, it is important to create agile city policy-making in order to deal with the occurring and future changes that are difficult to forecast. Ramos (2014) and other authors find it crucial to incorporate **complexity** into future studies’ approaches, which are considered as the systematic application of foresight - important to understand and incorporate the change. Deriving this approach at a practical level, would allow the city’s policies to be proactive, adaptive, and driven toward the preferred future, as opposed to reactive and misguided policies (Ramos, 2017), the ones where future happenings are not considered.

Foresight as future-intelligence-gathering (Kienegger, 2015) needs governance, which has been tested and combined with different approaches and traditions (e.g. technological forecasting or anticipatory democracy) that link foresight and governance (Ramos, 2014). The latest solution according to the most recent literature is seen in **anticipatory governance** that seeks to understand and shape the changes expected in the future by incorporating knowledge about the future in policies and decision making, in this way trying to proactively impact the long-term implications of its policies and decisions. Citizens’ involvement is crucial in creating the knowledge base that can raise awareness of the change (Ramos, 2014).

Anticipatory governance is a relatively novel and under-researched concept as can be seen by the results of the Scopus database search done in March 2021 for “anticipatory governance” as per article title, abstract or keywords search criteria. The total of 37 results in three subject areas of: Business, management & accounting, Economics, econometrics and finance and Multidisciplinary studies shows that this topic has been insufficiently explored by the researchers in these disciplines, as opposed to 142 results incorporating all subject areas (including biology, mathematics, technology, etc.). Graph 1 shows the rising trend in anticipatory governance research in recent years.



Graph 1: *Number (#) of research papers in Scopus database on the topic of anticipatory governance* (made by author)

The purpose of this paper is to present an overview of the anticipatory governance and foresight research through the state of the art review of its definitions, forms, tools, and practices, with a special focus on implications for cities i.e. urban development.

The overall need for this study is identified in bridging the gap in the literature by focusing on anticipatory governance (a type of governance that includes foresight and citizen participation) which is overlooked by the more popular concept of smart city governance with overly technocratic tendencies of the topic (Ramos, 2017). Smart city management shows more than twice as high popularity. The popularity of the concept can be observed by the Scopus database search conducted in April 2021, which brought 321 results in all areas and 51 results in three previously selected areas as described above. Although smart city governance means “better outcomes and more open governance processes” (Meijer and Rodríguez-Bolívar, 2016, p. 392) through the new ways of information and communication technologies (ICT) and human collaboration, it neglects to incorporate the future dimension in its planning processes, unlike anticipatory governance.

The aim of the study includes:

* Defining the anticipatory governance (AG) in a broad context;
* Explaining the evolution of the term AG, its precedent approaches, and components;
* Presenting foresight and identifying (participatory) foresight methods important to urban development context;
* Discussing and identifying the future research directions of the topic, with a special focus on urban development implications.

The other sections of the paper are organized as follows: Section 2 provides a historical overview and brief evolution of the anticipatory governance research; it lists various definitions formulated by previous studies, AG components and founding concepts. Section 3 introduces foresight and its most common methods while focusing on participatory methods used in an urban context. Section 4 discusses institutional use of anticipatory governance and foresight, simultaneously describing recent governmental and EU institutional agenda for policymaking. It also introduces AG and foresight implications for urban development, along with possible future actions and research. Section 5 concludes this seminar paper.

Theoretical background: Defining anticipatory governance

## Historical development and evolution of the anticipatory governance research

To get a better understanding of the term anticipatory governance, its genealogy is to be studied. The word “anticipation” originates from the Latin prefix ante-, meaning “before”, as well as “concerning to position, order, or time”. Latin word capere means “capable”, “capacity”, “to take into possession”. For this reason, practice i.e. exercise is central to anticipatory governance (Guston, 2014) as anticipation is about practicing/exercising a capacity for future purposes. However, according to Guston (2014), anticipatory governance is more than practice as it includes three different **capacities** defined by Barben et al. (2008). These are: 1) **foresight** as a pluralist approach that seeks multiple futures, 2) **engagement** as encouragement of exchange of ideas between different stakeholders, and 3) **integration** as overcoming the divide and creating the opportunities to develop the long-term capacity building.

The year 2001 marks the emergence of two strands of literature on anticipatory governance. The first one is related to public administration and management (e.g. Bächler, 2001 as noted by Guston, 2014), and the second one is related to environmental studies (e.g. Gupta, 2001 as noted by Guston, 2014). From this point, research has been expanded significantly to other strands of literature including research and innovation in general (e.g. Gudowsky and Peissl, 2016), emerging technologies (e.g. Sarewitz, 2011), genetics (e.g. Conley, 2020), nanotechnology (e.g. Wiek et al., 2016), automated vehicles (Milakis and Müller, 2021), climate (e.g. Serrao-Neumann et al., 2013), robotics (Diep et al., 2014), etc. Lehoux et al. (2020) discussed the responsible research and innovation (RRI) field of research that also implements future-oriented anticipatory forms of governance to analyse the benefits and risks of innovations.

## Exploring definitions of anticipatory governance

Several definitions of anticipatory governance have been found while reviewing the literature, showing the different terms and descriptions used to describe the core features of anticipatory governance. Before discussing them, it is interesting to address the necessary qualities of anticipatory governance: open-mindedness, curiosity and constant questioning of assumptions, and willingness to examine alternative possibilities (Fuerth, 2009).

Institute for the Future (2020, p. 1) brought forward some of the meanings of AG in 2020, and for some it signifies “incorporating forecasting, visioning, and participatory processes when setting public goals, engaging government institutions in committing to those goals, and measuring progress against them”. For others, it signifies “setting up rapid feedback loops between technical innovations and their social and environmental impacts to influence future development decisions in both academia and corporate R&D.”

According to the definitions listed in Table 1 below, anticipatory governance is at the same time a process and a system that uses foresight and other forms of anticipation processes in developing different actions and responses to future events. The role of **foresight** in the definitions is emphasized as an important tool that collects emerging knowledge that is to be used later by AG in the processes of policy or decision-making.

Table 1: Definitions of anticipatory governance

|  |  |
| --- | --- |
| **Definition** | **Author** |
| “A broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible”. | Guston, 2008, p. 6 |
| “Anticipatory Governance is a system of institutions, rules and norms that provide a way to use foresight for the purpose of reducing risk, and to increase capacity to respond to events at early rather than later stages of their development.” | Fuerth 2009, p. 29 |
| “Anticipatory governance is a mode of decision-making that perpetually scans the horizon for changes demanding adaptation in our plans and behavior. It can be regarded as a scalable system of systems, in which foresight is integrated at every level.” | Fuerth, 2009, p. 30 |
| “Anticipatory Governance denotes large scale participatory processes and systems for exploring, envisioning, direction setting and developing a strategy for a region.” | Ramos, 2017, p. 1 |

Source: *compiled by the author*

In its publication, OECD (2019) mentions a new type of AG - anticipatory innovation governance defined as “broad-based capacity to actively explore options as part of broader anticipatory governance, with a particular aim of spurring on innovations (novel to the context, implemented and value shifting products, services and processes) connected to uncertain futures in the hopes of shaping the former through innovative practice” (OPSI, 2019) that is innovation-oriented with a more narrow scope than AG in general.

## Anticipatory governance system and its foundations

This sub-section explains the core components and functioning mechanisms of anticipatory governance. According to Fuerth (2009), anticipatory governance comprises of four basic components: a **foresight system**; a **networked system** for integrating foresight and the policy process; a **feedback system** to evaluate its performance and to manage institutional knowledge, and **open-minded** institutional **culture**.

Anticipatory governance is a scalable process transferable to every level of governance (from local to global) as it contains similar relationships on all levels. It represents the environment with characteristics that include interactions of its sub-systems for foresight, networking, and feedback (ibid). Fuerth (2009) tried to summarize AG operations into the following activities: 1) supporting foresight by encouraging networking between public and private organizations employed to unify forecasting, futuring, and modelling, 2) employing specialized systems to identify and track signals of change, 3) evaluating these signals and incorporating them in development of alternative scenarios and simulation testings to see if they should be included in policies, 4) using feedback systems for a re-examination of policies, developing networked processes for collection, assessment and analysis of intelligence.

Although the first concepts of AG date from 2001, its foundations are found in the following seven traditions and discourses identified by Ramos (2014). Following traditions also present a background for designing anticipatory governance **strategies** via a service design approach that enables adaptation to diverse needs and situations (ibid).

1. Science, Technology and Innovation Foresight (STIF) that include priorities such as policy formulation, strategy and priority setting, cooperation and networking, generating visions of the future, promoting public debate, identifying key barriers and drivers of STI, encouraging strategic and future thinking.
2. Anticipatory Democracy (AD) – developed in the 1970s in the United States to engage citizens and other community stakeholders in processes of policy development together with policymakers in the context of emerging futures.
3. Futures Commissions (FC) - semi-independent research institutes/agencies established to provide a foresight function for both government and the public, which consequently can influence policy development.
4. Foresight Informed Strategic Planning (FISP) – participatory planning which engages key stakeholders in discussion of the long-term issues being mutually experienced (includes methods such as search conference methods and scenario planning).
5. Transition Management (TM) – long-term systemic strategy for reaching sustainable development goals and visions.
6. Integrated Governmental Foresight (IGF) - integrates intelligence and foresight activities across governmental departments, joining synergies and similarities in regards to systemic policy.
7. Network Foresight (NF) – includes usage of ICT systems on interactive web platforms that are generally accessible to everyone interested and capable to contribute.

Foresight

As noted in section 2.2, foresight is a central part of anticipatory governance. In an attempt to back up this thesis, additional text mining of AG definitions and components is done when trying to create an AG word cloud. From 255 words analysed (with minimum 2 frequencies set), the word “foresight” resulted as the one with the most frequencies (#14) as shown in Figure 1.



Figure 1. *Word cloud for anticipatory governance* (author’s work in software WordItOut)

Per Fuerth (2009), foresight is the capacity to anticipate alternative futures and an ability to visualize their multiple outcomes in form of consequences. It is a way to visualize, run through and improve the actions without testing them in reality, where the error consequences are serious and irreversible (ibid). According to the same author, the purpose of foresight (as a part of governance) is to enhance the ability of decision-makers to prepare for long-term events for the benefit of the citizens.

Foresight studies are often complicated, require many resources including financial ones with an aim to provide important information to the government, industry and academia for technology planning and knowledge expansion (Gibson et al., 2018).

The concept of foresight is often confused with the concept of vision, but the two differ significantly. Vision is likely to be seen as a fixed image of the future while foresight is conditional and subject to a change as it presents a continuous effort to show different possibilities of the future that helps in making decisions (Fuerth, 2009). Foresight practitioners welcome alternative perceptions of the future as essential resources, unlike vision makers who tend to create unique vision (ibid).

According to Gibson et al. (2018), there is no unique framework to develop and plan foresight activities. However, per Foresight futures (2021) first step in exploring the possible futures starts with defining the foresight framework, a structure that encourages generating different perspectives to seek new threats and possibilities within external changes, to prepare new policies and strategies for generated futures, and to decide on the action to take today to prepare towards a preferred future. The generic foresight process framework developed by Voros (2003) consists of inputs, analysis, interpretation, prospection, outputs and strategy/policy. Another framework found in the literature is presented by Keenan (2007) as five mental stages of foresight which include understanding, synthesising models of the future, analysis and selection, transformation and finally action. The last one identified is by Inayatullah (2008) as six pillars of future thinking for transforming: mapping, anticipating, timing, deepening, creating alternatives and transforming.

## Foresight methods

According to EC (2020), foresight is a discipline of “exploring, anticipating and shaping the future” that helps in building and using collective intelligence in “a structured and systematic way to anticipate developments and better prepare for change”. Foresight employs a vast number of methods that can be chosen, adapted, and personalised according to the specific type of foresight and practitioner’s choices (Kienegger et al., 2015). Unlike foresight, a specific set of methods for “anticipation” are not currently identified and available (ibid). However, some authors (e.g. Gudowsky and Peissl, 2016) find forward-looking and participation as essential tools to govern innovation actively and responsibly with a goal of developing sustainable long-term strategies that include socio-technical changes.

Practical foresight guide (Jackson, 2013) and Foresight methodologies guide (UNIDO, 2004) list and describe the most commonly used methods such as: brainstorming, causal layered analysis, chaos theory, cross-impact analysis, decision modelling, Delphi method, environmental scanning, expert panel, forecasting, futures wheel, simulation, gaming methods, participatory methods (focus groups, interviews, mapping techniques, narrative analysis, role-playing), prediction market, road-mapping, scenarios, text mining, trend impact analysis, visioning and others.

The focus of this paper is placed on **participatory** methods that combine scenario building and gaming opportunities to enable the application of future thinking for policy-making, which is used by practitioners when dealing with within a local government context. The focus is on participation, as expert forward-looking failed to include diverse opinions, therefore stakeholder engagement became a standard in long-term perspectives (Gudowsky and Peissl, 2016). According to the same authors including laypeople into forward-looking science, technology and innovation (STI) governance is underexplored, but is crucial in co-creating valuable knowledge together with other stakeholders and experts (ibid).

## Scenario-based foresight methods

Scenarios may be developed by different sets of methods at diverse workshops by expert groups or may derive from Delphi or other survey results, etc. (UNDIP, 2004). Practically any forecasting or foresight approach can be a motive for a scenario generating exercise. Scenario planning is well-known and often used technique for thinking about the future. Building scenarios help in identifying future opportunities and possibilities and at the same time giving assurance when acting within uncertainty (Jackson, 2013). Scenario planning questions previously made assumptions about the future and creates future alternatives that can be used by decision-makers in determining their response. It can be used to (ibid): explore uncertainties and test for limits, order alternative futures, identify emerging risks and opportunities, improve future assumptions, derive new vision and strategy development, risk assessments of projects and organizations, or to rehearse the future.

According to Lehoux et al. (2020), RRI and participatory foresight practitioners should formulate scenario-based methods in order to use experts and non-experts in analysing the benefits of the past, reconsidering the present, and in forming the future scenarios and possibilities. This is done to inform anticipatory governance (ibid). Boenink (2013) considers scenarios of the future important for considering and studying new and emerging science and technologies. Similarly, Urueña (2019) finds the creation of future scenarios as a valued methodological tool for shaping the anticipatory governance of emerging technologies.

## Gaming methods

Gaming methods in foresight are also very popular and useful especially when the goal is to include people in community planning activities to get the insight of the problem, to deal with future challenges or different upcoming or imaginary changes. In this way, gaming practitioners can generate new ideas, test behaviours, encourage the learning process, and create a good atmosphere for productive discussions between different stakeholders.

Looking retrospectively in the history, first games invented were war games (since the 19th century), followed by serious games in the 1970s as determined by Abt (1970). Their application is noted mostly in the social sciences, at the same time noting greater engagement of participants in physical games vs. online games, with a new trend of future-oriented games identified (Bontaux et al., 2020).

Games are considered a powerful method to explore beforehand possible ways of actions, different solutions and measures. This is impossible to perform under the direct pressure of reality. Circumstances created in the future games create a safe space to think because there is no “urgency” and participants have creative freedom (Bontaux et al., 2020). **Uncertainty**, noted previously as the backbone of the chance and the future, is the main feature of games as well, but in the case of games, it offers excitement needed for participants/players.

## Scenario Exploration System (SES)

Scenario Exploration System is a foresight gaming system developed by the Joint Research Center’s (JRC) of the European Commission. The objective of SES is to facilitate the application of future predictions in the area of public policy-making. The SES is designed to engage different stakeholders in systematic long-term thinking and to explore alternative futures for particular issues on a variety of topics (in less than three hours). The four characteristics of the tool are: versatility, a wide range of potential users, the ability to interact with a wide variety of participants and circumstances, and adaptability (Bontaux, 2020).

This gaming system includes advantages of both scenario-based methods and gaming-based methods, as it is a combination of both. In SES four scenario explorers take up their long-term objectives with given resources, interact with other scenario explorers, and are subjected to foreseen and unforeseen events to which they need to react. The public voice judges the actions of scenario explorers.

There are different Scenario Exploration System versions and adaptations organized so far:

* Circular ocean: the goal was to find solutions for fishing nets and ropes waste in northern Europe; SES managed to create a constructive conversation among the stakeholders involved (fishermen, port commanders, SMEs and fisheries agencies;
* Food safety: conversations were opened about policy work on food safety and food innovation after 15 years;
* Dragon Star: discussions between European and Chinese stakeholders involved in development and innovation activities (Research & Innovation) were initiated in order to create a long-term development strategy;
* Mobility is a serious game: representatives of the local and central government, business sector and NGOs are to meet in an educational environment and discuss different mobility scenarios, for example on the topic of autonomous vehicle implementation;
* Climate KIC: the topic is carbon-free cities where contrasting scenarios are given to participants; for example market-driven vs. a policy-driven scenario according to the local vision of the city of Bologna and Frankfurt;
* EU innovate: participants interact with the radical social, political and economic changes that should take place by 2050, 4 scenarios for 4 opposing sustainable lifestyles are possible with a role of the citizen innovator and the “post-truth” public voice;
* Application of nanotechnology: opportunity to talk about research directions with different interesting parties in different scenarios;
* Migration to the EU: opportunity to talk about different scenarios with different interested parties from pro-immigration to anti-immigration populists.

As previously described, SES can be adapted to different policy contexts, and for each, it offers a collaborative and experimental space that can be used for innovative policy making.

Discussion

Future studies, as “an empirical and scientifically-based approach to understanding the future” (Lombardo, 2008, p. 109), seek to capture, understand and analyse possible future events, innovations and their implications in forms of opportunities and/or threats for humanity. This discipline is not novel, but its importance is especially recognized and emphasized in these special conditions of global pandemics of Covid-19.

This might be the right moment for the novel concept of anticipatory governance to be recognized along with its core component – foresight, especially taking into consideration global agenda oriented on sustainability (2030 Agenda for Sustainable Development) and 17 adopted Sustainable Development Goals (SDGs) by all UN member states. Zovko (2013) finds exploration of the future as a key point to sustainable development. This is particularly emphasized by European Commission (EC) in the newly issued 2020 Strategic Foresight Report (SFR) that discusses resilience as the central theme of the mentioned report.

Per Political Guidelines for the next European Commission (for period 2019-2024) a strategic long-term direction is to achieve the transition towards a green, digital and fair Europe. The goal of the Commission is to put **strategic foresight** at the heart of EU policymaking with a goal to stimulate strategic thinking and form EU policies and initiatives (EC, 2020). The mentioned first annual SFR defines how foresight will influence policies to strengthen the EU’s resilience (ability to withstand and cope with challenges) in four interconnected dimensions: social and economic, geopolitical, green, and digital (ibid). The report analyses the levels of the EU’s resilience in the Covid-19 crisis. As seen in Figure 2, by strengthening capacities and mitigating vulnerabilities Europe can improve resilience, at the same time accelerating or decelerating relevant megatrends opens up new opportunities in four dimensions.



Figure 2. *Link between strategic foresight and resilience* (European Commission, 2020)

Forward-looking culture in policymaking in the EU is important to deal with complex changes, and it is the basis for forward-looking policies supported by participatory foresight (ibid).

Reviewing more globally, the most powerful economies (Israel, Sweden, Finland, Japan, Korea, Switzerland, US) invest in future studies research, with an aim at driving their society and economies towards sustainable development (Zovko, 2013). The above countries have economic and human potential for conducting such research, and it is expected for them to become leaders in future development. It is interesting to note that these countries coped relatively well with the Covid-19 crises in comparison to other countries. The academic community can help other countries to join the development of this scientific discipline so that future scenarios include local differences and preferences aimed at the ultimate goal of fulfillment of global progress and sustainability (ibid).

## Implications for Urban Development

The importance of anticipatory governance is noted in several studies comprising the city context. Most of them are showing just fragments or initial emergence of AG which shows that AG research is scarce, but also shows the novelty of AG concept, especially within the city concept, in both scientific and practical approaches. One of the rare studies that incorporated AG in its research discusses the governance during Covid-19 pandemics in Italy. In their survey of 25 municipality mayors, Garavaglia et al. (2020) identified four key issues related to urban governance: 1) the importance of adaptive leadership and of anticipatory governance frameworks that provide direction in emergency situations, 2) the importance of promoting institutional spaces for cooperation and collaboration with citizens as volunteers and of other stakeholders willing to contribute to public value co-creation, 3) the role of technology as an enabler and medium for sharing information and crowdsourcing resources, and 4) the importance of trusted platforms for knowledge sharing among the mayors and with other relevant organizational stakeholders.

In 2013, Wiek et al. defined a research agenda to support anticipatory governance of nanotechnologies in cities. “Nano and the City” research program conducted in Phoenix, Arizona combined the AG principles (imagining, designing and influencing emerging technologies) with transformational sustainability science (giving a structured framework). At the end of the same project, Wiek et al. (2016) confirm and invite for sustainable and responsible innovation that will incorporate AG with an aim to avoid shortcomings of conventional principles dominating emerging technologies.

The fragments of AG governance are recognized in the study made by Termini & Kalafatic (2021) and Derickson (2017). Termini & Kalafatic (2021) presented the results of the study in Pennsylvania (USA) that explored local government’s work in adapting to climate changes. Local officials did not recognize their work with water management as an adaptation to climate change although in two municipalities they were reacting to the water threats, and in a single case, officials used a proactive approach with elements of anticipatory governance where they were building up the greater capacity of the water system to address future risks.

Derickson (2017) discusses two popular trends in urban governance, smart and resilient cities, which represent the governance of the city as a complex adaptive system that tends to anticipate and affect its future. She highlights the overly technocratic realm that is solely focused on surviving the possible future shocks and maintaining the status quo, as opposed to new political and social urban formations. This “post-political” urban governance tends to use collected and aggregated data in predicting and anticipating futures, but it lacks a non-technical side and citizen collaboration to be called anticipatory governance.

Two studies found in the literature discuss the importance of foresight, not mentioning AG. The first one is presented by a case study of a participatory foresight project that included citizens, experts and stakeholders in planning the future of **aging** in the city. The results show that urban governance needs to consider both technological and human factors when considering innovation (Gudovski et al., 2017). The other paper by Wolfram (2018) highlights the importance of sustainability foresight on the example of three South Korean cities where the assessment of the transformative capacity of studied cities finds the defects in local policies as they automatically follow higher-level policies without contextualization and adjustments, seeking to reconfigure social, technological and ecological systems.

## Future actions and research

Searching the Croatian Scientific Bibliography (CROSBI) and Scopus database, research papers with a topic of anticipatory governance in Croatia have not been found which proves under researched topic in all public administration levels.

Meanwhile, few studies containing foresight topics have been researched by Croatian authors (e.g. Zovko (2013) and Dabić in Gibson et al. (2018)). There is a study by Nyuur et al. (2015), covering the corporate sector, focused on the foresight capacities of small and medium companies in Croatia. Foresight studies at local, regional or central government have not been identified which points to a great gap in the literature that should be investigated. Such results may point to scarce or non-existing foresight included in the policies. To fill this gap further, the investigation is needed primarily in implementing AG and foresight practices in the public sector and in highlighting the role of citizens and other stakeholders in cities especially.

Mentioned gaps in the literature can be addressed by the following research propositions:

As insufficient research from the public administration perspective has been noted as a finding and research gap, solutions can be developed by intensifying the academic and public sector cooperation, which will lead to more foresight implementation studies.

**Proposition 1.** Conducting (gaming) scenario building studies within higher education institutions (HEI) and public institutions while working on tackling different future problems in different areas. By incorporating foresight tools, it is possible to raise awareness among public officials and show the importance of why it is beneficial to include anticipatory governance in urban governance, making it part of strategies, and later, on policies and legislation. The needs of citizens and other stakeholders should be included as well.

**Proposition 2**. Measuring the impact of pilot foresight studies and final solutions in the forms of public policies is very important. For that purpose, there is a need to develop and test impact indicators to measure AG benefits.

Conclusion

Anticipatory governance is required at every scale, from communal to global (Fuerth, 2009). It should be designed to employ foresight that would result in governments that are able to foreseen and adapt to future changes.

In the process of establishing AG, city governments should establish well-resourced systems and structures in partnership with citizens, which would allow continuous citizen involvement (Ramos, 2017) in form of different participatory foresight methods. This paper explains the main principles of AG and foresight, at the same time explaining three different participatory foresight methods that can assist local governments (cities) to launch foresight activities in an attempt to gather knowledge that will be later used in managing the city. Having the tools (different 3 SES games including city greening, future mobility and eco-innovation) and tool knowledge, the author proposes conducting the SES game with graduate students during the course Smart city management at the Faculty of Economics, Business and Tourism, as a first step in promoting participatory foresight in the Croatian context, needed for urban development.

References

1. Abt, C. C. (1970). *Serious Games*. Viking Press, New York.
2. Bächler, G. (2001). Conflict transformation through state reform. In: *Berghof Handbook for Conflict Transformation*.
3. Barben, D., Fisher, E., Selin, C., Guston, D.H. (2008). Anticipatory governance of nanotechnology: Foresight, engagement, and integration. In: Hackett, E.J., Amsterdamska, O., Lynch, M., Wajcman, J. (eds). *The Handbook of Science and Technology Studies*. Cambridge, MA: The MIT Press, pp. 979–1000.
4. Boenink, M. (2013). Anticipating the future of technology and society by way of (plausible) scenarios: fruitful, futile or fraught with danger?. *International Journal of Foresight and Innovation Policy*, 9, Nos. 2/3/4, pp.148–161.
5. Bontoux, L., Sweeney, J. A., Rosa, A. B., Bauer, A., Bengtsson, D., Bock, A. K., ... Watson, R. (2020). A Game for All Seasons: Lessons and Learnings from the JRC's Scenario Exploration System. *World Future Review*, 12(1), pp. 81-103.
6. Bourgeois, R., Penunia, E., Bisht, S., Boruk, D. (2017). Foresight for all: co-elaborative scenario building and empowerment. *Technol. Forecast Soc. Change*, 124, pp. 178–188.
7. Conley, S.N. (2020). Who gets to be born? The anticipatory governance of pre-implantation genetic diagnosis technology in the United Kingdom from 1978–2001. *Journal of Responsible Innovation*, 7(3), pp. 507-527.
8. Derickson, K. D. (2017). Urban geography III. *Progress in Human Geography*, 42(3), pp. 425–435.
9. Diep, L., Cabibihan J. J., Wolbring, G. (2014). Social robotics through an anticipatory governance lens. *Lecture Notes in Computer Science* (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 8755 LNCS, pp. 115-124.
10. European Commission (2021). 2020 Strategic Foresight Report: Charting the course towards a more resilient Europe. Available at: <https://ec.europa.eu/info/strategy/strategic-planning/strategic-foresight/2020-strategic-foresight-report_en> (Accessed: March 30, 2021).
11. Foresight Futures (2021). Foresight Approaches. Available at: <https://foresightfutures.net/foresight-approaches> (Accessed: March 30, 2021).
12. Fuerth L.S. (2009). Foresight and anticipatory governance. *Foresight*, 11(4), pp. 14-32.
13. Garavaglia, C., Sancino, A., Trivellato, B. (2021). Italian mayors and the management of COVID-19: adaptive leadership for organizing local governance. *Eurasian Geography and Economics*, 62(1), pp. 76-92.
14. Gibson, E., Daim, T., Garces, E., Dabic, M. (2018). Technology Foresight: A Bibliometric Analysis to Identify Leading and Emerging Methods. *Foresight and STI Governance*, 12(1), pp. 6–24.
15. Gudowsky, N., Peissl, W. (2016). Human centred science and technology-transdisciplinary foresight and co-creation as tools for active needs-based innovation governance. *European Journal of Futures*, 4(8).
16. Gudowsky, N., Sotoudeh, M., Capari, L., Wilfing, H. (2017). Transdisciplinary forward-looking agenda setting for age-friendly, human centered cities. *Futures*, 90, pp. 16-30.
17. Gupta, A. (2001). Searching for shared norms: Global anticipatory governance of biotechnology. PhD Thesis, Yale University, New Haven, CT.
18. Guston, D. H. (2014). Understanding ‘anticipatory governance’. *Social Studies of Science*, 44(2), pp. 218-242.
19. Inayatullah, S. (2008). Six pillars: futures thinking for transforming. *Foresight*, 10(1), pp. 4-21.
20. Institute for the future (2020). Sustanability Outlook Scenario Perspectives 2009-2020: Anticipatory governance. Available at: <https://www.iftf.org/uploads/media/SR-1272_anticip_govern-1.pdf> (Accessed: March 30, 2021).
21. Jackson, M. (2013). Practical foresight guide. Available at: <https://www.shapingtomorrow.com/media-centre/pf-ch03.pdf> (Accessed: March 30, 2021).
22. Keenan, M. (2007). Combining Foresight Methods for Impact, NISTEP 3rd International Conference on Fore-sight, Tokyo. Available at: <http://www.nistep.go.jp/IC/ic071119/pdf/3-3_Keenan.pdf> (Accessed: March 30, 2021).
23. Kienegger, M., Hörlesberger, M., Giesecke, S. (2015). From Foresight to Anticipation. Austrian Institute for Technology. First International Conference on Anticipation in Trento, Italy. Available at: <http://www.projectanticipation.org/attachments/article/95/Kienegger%20et%20al..pdf> (Accessed: March 30, 2021).
24. Lehouxa, P., Millerc, F. A., Williams-Jones, B. (2020). Anticipatory governance and moral imagination: Methodological insights from a scenario-based public deliberation study. *Technological Forecasting & Social Change*, 119800.
25. Lombardo, T. (2008). *Contemporary Futurist Thought*. Author House, Bloomington, Milton Keynes.
26. Meijer, A., Rodríguez-Bolívar, M. (2016). Governing the smart city: A review of the literature on smart urban governance. *International Review of Administrative Sciences*, 82, pp. 392–408.
27. Milakis, D., Müller, S. (2021). The societal dimension of the automated vehicles transition: Towards a research agenda. *Cities*, 113, 103144.
28. Nyuur, R.B., Brečić, R., Sobiesuo. P. (2015). Foresight capabilities and SME product/service adaptiveness: the moderating effect of industry dynamism. *International Journal of Foresight and Innovation Policy*, 10, Nos. 2/3/4, pp.145–164.
29. OECD (2019). Envisioning the future, in Public Value in Public Service Transformation: *Working with Change*, OECD Publishing, Paris. doi: https://doi.org/10.1787/8b310079-en.
30. Ramos, J. M. (2014). Anticipatory governance: Traditions and trajectories for strategic design. *Journal of Futures Studies*, 19(1), pp. 35-52.
31. Ramos, J. M. (2017). Anticipatory governance and a city as a commons. Available at: <https://www.linkedin.com/pulse/anticipatory-governance-city-commons-jose-ramos/> (Accessed: March 30, 2021).
32. Sarewitz, D. (2011). Anticipatory Governance of Emerging Technologies. *International Library of Ethics, Law and Technology*, 7, pp. 95-105.
33. Serrao-Neumann, S., Harman, B. P., Low-Choy, D. (2013). The Role of Anticipatory Governance in Local Climate Adaptation: Observations from Australia. *Planning Practice and Research*, 28(4), pp. 440-463.
34. Termini, O., Kalafatis, S. E. (2021). The Paradox of Public Trust Shaping Local Climate Change Adaptation. *Atmosphere*, 12, no. 2: 241.
35. UNIDO – United Nations Industrial Development Organization (2004). Foresight methodologies guide. Available at: <https://www.tc.cz/files/istec_publications/textbook2revisedcf_1171283006.pdf> (Accessed: March 30, 2021).
36. Urueña, S. (2019). Understanding “plausibility”: A relational approach to the anticipatory heuristics of future scenarios. *Futures*, 111, pp. 15-25.
37. Voros, J. (2003). A generic foresight process framework. *Foresight*, 5(3), pp. 10-21.
38. Wiek, A., Guston, D., van der Leeuw, S., Selin, C., Shapira, P. (2013). Nanotechnology in the City: Sustainability Challenges and Anticipatory Governance. *Journal of Urban Technology*, 20(2), pp. 45–62.
39. Wiek, A., Foley, R. W., Guston, D. H., Bernstein, M. J. (2016). Broken promises and breaking ground for responsible innovation – intervention research to transform business-as-usual in nanotechnology innovation. *Technology Analysis and Strategic Management*, 28(6), pp. 639-650.
40. Wolfram, M. (2019). Assessing transformative capacity for sustainable urban regeneration: A comparative study of three South Korean cities. *Ambio*, 48, pp. 478-493.

**MODELLING OF INTERNAL ORGANIZATION AND EXTERNAL CUSTOMER JOURNEYS IN SMART CITIES**

INTRODUCTION

During the past years, many authors have recognised that the internal business process initiatives are not aligned with the external, customer’s needs. Within the local government perspective, customers are mostly identified as citizens (and businesses). The objective and biggest challenge of the urban development of local governments is to provide efficient and cost-effective service to citizens and businesses (City of Zagreb, 2018). They are under the immense pressure to conduct reforms and transition to smart cities.

Even though citizens were supposed to be in the focus of any local-government-related improvement initiative, quite frequently this is not the case. In the context of business and IT transformations that also encompass transitioning to smart city services, local governments, just like any other organizations, are focused primarily on their own internal organization – which mainly implies conducting initiatives such as process cost or time reduction through the optimization of processes and organizational units.

This chapter defines critical concepts such as Business Process Management (BPM) which includes identification, discovery, analysis, redesign, implementation and control, as well as Customer eXperience Management (CXM), which in the context of local governments and smart cities includes analysis of the experiential world of the citizen, design of brand experience, structuring the citizen interface, and continuous innovation (Schmitt, 2003; Dumas *et al.*, 2018). While in their traditional form these two concepts remain at a distance, today more than ever it becomes relevant to study their touchpoints and reveal opportunities for making current services of the city “smart” enough to cope with the latest technological trends recognized globally.

For several decades, business process management has been around as one of the key approaches to optimize the performance of the organizations (Dumas et al., 2018). At the same time, customer experience management has been widely adopted in order to have a positive effect on the analysis and the optimization of the experience of the customers (Schmitt, 2003). BPM enables capturing, analysis and redesign of internal processes in order to transition to an intelligent or smart city. Establishing and maintaining the repository of internal processes was recognized as one of the first steps of creating smart cities (Vidovic, 2015).

According to Jeet (2017), BPM helps build smarter cities by enabling:

* Enhanced e-Governance
* Breaking the silos
* Real-time Processing
* Rapid adapting to change

One of the examples of the application of BPM methods and tools, among others within the context of citizen enablement, is the City of Zagreb, where multiple projects were done in the course of the last decade, and it was recognised as the best practice within organizational development domain (City of Zagreb, 2018). Nevertheless, this example be related to the *Open process innovation concept*, which is identified as an involvement of citizens (and businesses accordingly) within the business process management initiatives (Niehaves and Malsch, 2009).

CONVERGENT MODELLING OF THE INTERNAL ORGANIZATION AND EXTERNAL CUSTOMER JOURNEYS IN SMART CITIES

While the current approaches mostly considered modelling of organizational processes from the internal perspective, business process management and customer experience management convergent approach (BPM-CXM) was developed which considers both the internal and external (customer’s, user’s, citizen’s) perspective (Pavlic and Cukusic, 2019b; Pavlic, 2021). Other than modelling and analysis of the internal processes, the approach elaborates on the parallel modelling and the analysis of customer journeys, with a specific focus on the analysis of the touchpoints with the customers (citizens). Other than the mentioned convergence approach, there are also a number of other authors who recognized the importance of including customer’s perspective within the internal transformation projects (Neubauer, 2009; Botha and Rensburg, 2010; Becker *et al.*, 2011; Gersch, Hewing and Schöler, 2011; Johnston and Kong, 2011; Botha, Kruger and de Vries, 2012; Norton and Pine II, 2013; Bergh, Thijs and Viaene, 2014; Schmiedel, Vom Brocke and Recker, 2014; Trkman *et al.*, 2015; Gloppen, Lindquister and Daae, 2016; Bernardo, Galvina and de Pádua, 2017; Frank *et al.*, 2020).

Without a clear connection between the internal processes of the local government and the external journeys of the citizens, it is not clear optimization of which internal process leads to the improvement of which journey, and vice versa. Design, modelling, analysis and testing of the internal processes of the local governments should be performed in convergence with the design, modelling, analysis and testing of the citizen’s journeys (and the overall experiences) (Davis, 2011). That way, the prerequisites for setting up smart services would be met by providing the as-is transparency and a polygon for the to-be redesign within the 4 crucial segments:

* Process
* Organizational
* Technological
* Citizen-experience

*CITIZEN’S PERSPECTIVE WITHIN THE PROCESS MANAGEMENT INITIATIVES*

Even though local governments and organizations in general frequently mention customers (citizens) as an integral part of the internal process reorganizations, traditional business process management approaches are primarily oriented on the modelling and the analysis of internal processes (Niehaves and Plattfaut, 2010; Temkin, 2010; Davis, 2011; Mendling *et al.*, 2018; Helmy *et al.*, 2020). However, external perspective which considers citizens and their journeys is becoming more and more relevant (Rosemann, 2014; Gloppen, Lindquister and Daae, 2016). Some authors have recognized this synergy with the external perspective as the future of the business process management (Richardson, 2016).

Many authors have emphasised the importance of customer oriented process design (Rajala and Savolainen, 1996; Bolton, 2004; Alt and Puschmann, 2005; Heckl and Moormann, 2007; Brocke, Uebernickel and Brenner, 2010; Kohlbacher and Weitlaner, 2011; Margaria *et al.*, 2012; Esfahani, Rahman and Zakaria, 2013). This is especially relevant within the strategic, early phases of process management and customer experience management initiatives. It is crucial to have an understanding of the external processes related to citizens and their needs – in order to be able to setup and prioritize internal organizational improvement initiatives. This is especially relevant in the context of transitioning from the *traditional* to *smart* cities.

Modelling and the analysis of the perspective of the external citizens in convergence with the internal organization can be recognized as significant challenges not only in the domain of methodologies or operationalized approaches, but also the technological tools to support this.

*PROCESS MANAGEMENT PERSPECTIVE WITHIN THE CITIZEN’S EXPERIENCE*

In order to improve the orientation of cities towards their citizens and form an enabler for smart cities implementation, coordinated changes of internal business processes, as well as IT systems, which take citizen’s expectations into account are necessary. For the experience of citizens to be improved, it is necessary to develop goals, identify key internal processes and key performance indicators, and associate the requirements of citizens with city’s internal processes. According to that, priorities for the future initiatives in the domains of business process management and customer experience management should be set.

By better understanding of citizen’s experience, improvements of relevant internal processes in the context of optimizing the individual touchpoints as well as the entire journey of citizens are possible (Osman and Ghiran, 2019). Feedback of citizens in regards to their needs can play a crucial role in customer-oriented smart services.

The analysis of customer’s needs should be the key prerequisite for any process improvement initiative (Chen, Daugherty and Landry, 2009). Process improvements should be measured in the context of the evaluation of customer’s satisfaction (Lee *et al.*, 2010). By monitoring the performance of internal processes and external experiences, priorities for optimizing those processes that have a significant impact on customer’s experience can be established (Ruland, 2016). That way, the root causes for increasing or decreasing customer’s satisfaction could be explained through how internal processes are defined or performing (vom Brocke and Rosemann, 2010).

BPM-CXM CONVERGENCE THEORETICAL MODEL

Process design and business process management were recognized as one of the main factors of achieving customer satisfaction (Scheer et al., 2005; Kumar et al., 2008). Customer experience management can be perceived through individual phases and activities of the business process management lifecycle (Ruland, 2016). According to that, in order to enable customer’s experience optimization, modelling of customer experience or journeys should be incorporated within the business process management systems (Osman and Ghiran, 2019). This is very relevant in the context of smart cities, where redesign of current processes and organizational units is necessary in order to use technological advantages and serve citizens in a more efficient way.

A high-level concept of BPM-CXM convergence model structured around the BPM lifecycle is presented on *Fig 1*. BPM-CXM convergence model should be used as the main starting point for process and citizen experience analysis discussions for transitioning to smart cities, as it is structured in a way that would facilitate the integrated analysis of customer experience and internal business processes. Model proposes that the customer experience is designed and analyzed by using customer journey mapping, which is used as an input for strategic identification of processes for initiating process redesign (BPM) initiatives (Flint et al., 2005; Chen, Daugherty and Landry, 2009; Lee et al., 2010; Davis, 2011; Moormann and Palvolgyi, 2013; Vanwersch et al., 2015). The approach reflects the way customer experience can be perceived and analyzed through the whole process management lifecycle (Ruland, 2016). It supports the emphasis on the analysis of touchpoints between the internal organization and the external customers, while using the proven best practices from both management of business processes as well as customer experience.

Diagram

Description automatically generated

Figure 1. *BPM-CXM convergence model* (Pavlic and Cukusic, 2019b; Pavlic, 2021) *(based on (Dumas et al., 2018))*

Other than the identification of the internal processes, BPM-CXM convergent approach proposes the identification of the processes related to the customers external to the organization (Ruland, 2016). This is a prerequisite for a joint analysis within the further steps of the methodology. Compared to the traditional process and experience management methods, the convergent approach imposes a number of adjustments, which are briefly outlined below (Pavlic, 2021).

Organizations should have an insight into how satisfied their customers are with services provided, as well as how well the internal processes are performing (Flint et al., 2005). Priorities for the redesign in the context of introducing the smart services should be set in a way that the initiatives address those internal processes which have the greatest impact on the customer, and are not performing well at the time (Gustafsson and Johnson, 2006; Kreuzer, Röglinger and Rupprecht, 2020). By improving those processes, there should be the biggest “return of investment” when looking at the effects towards increasing customer’s satisfaction while keeping the internal processes optimized.

When the processes are designed, links between the internal processes and customers should be established (Kaplan and Norton, 1996; Klose, Knackstedt and Becker, 2005; Ruland, 2016). Links can be represented in a visual form by using the so called *touchpoints* (Botha and Rensburg, 2010). Touchpoints should provide a more detailed information about the experience of the customer for each segment of the journey, and direct the organization into improving those processes generating the worst experience for the customers (Meyer and Schwager, 2007). Convergent BPM-CXM approach ensures that the links or touchpoints between the organization and customer are established. It is also important to point out that the touchpoint’s analysis should be put into the end-to-end context by analyzing the entire journey of the customers – which begins before the interaction with the organization, and ends after (Voorhees et al., 2017). The mentioned visual representation of touchpoints and journeys, as well as establishing their connections with the internal processes, is useful not only for the alignment of the internal processes with the needs of the customers, but also for delivering better services (Lee and Karahasanović, 2013).

In order to be able to identify if the internal processes would really result in an amazing experience for its customers, organizations should quantify the relative importance of each phase of the journey for the customer (Payne and Frow, 2005). This analysis should also provide an explanation on why the customer’s satisfaction is dropping within certain phases of the journey (vom Brocke and Rosemann, 2010).

The impact and performance of processes from customer’s perspective can be analyzed by monitoring the data acquired from customers (Botha and Rensburg, 2010). Certain performance measurements are controlled in order to evaluate if processes are performing on a desired level – and this also provides an indication on which processes should be improved (Ruland, 2016). Techniques that can be used in order to gather data and evaluate the experience of customers include focus groups, 1 on 1 interviews, phone and online surveys and others (Schmitt, 2010). Techniques for internal process analysis include the analysis of the weak points of the organizational unit or a processes, process and organizational simulations, static and dynamic analysis of process and organizational unit cost and time, etc. (Van Hee and Reijers, 2000). The mentioned techniques and evaluations should result in an initial improvement proposals (Dumas et al., 2018). Any interaction (touchpoint) between the customer and the organization generates certain data that can be stored and analyzed (Bolton, 2004). This data can be collected manually, but also automatically from the existing IT systems. Based on the predefined metrics and indicators, information that should be used within the next iteration of the internal process and/or customer journey design are gathered.

When the processes and/or customer journeys are redesigned and improvement proposals are approved, implementation of changes occurs. It is important to keep in mind that the implemented changes will have an effect not only on the internal organization, but also on the journey of the customer. This is especially relevant in the context of the mentioned touchpoints between the internal organization and the customer. Only when the organizations redesign and implement their own internal processes in a way that they fully support the needs of their customers, strategic competitive advantages can be achieved (Meyer and Schwager, 2007; Botha and Rensburg, 2010).

BPM-CXM OPERATIONALISED MODEL

In order to make the proposed theoretical model feasible in practice, models, object and attributes were adjusted and/or developed within the market leading business process management system – ARIS. ARIS tool and ARIS Value Engineering (AVE) were selected due to their wide usage within the EMEA region (Kapulin, Russkikh and Moor, 2019).

The set of models and objects are formulated within the BPM-CXM convergence model in a following way (Pavlic and Cukusic, 2019b):

* 1. **Process and customer experience identification.** High-level processes and customer experience environments are identified by defining internal process and external customer experience landscapes within the entry model.
  2. **Process and customer experience discovery**. Current (as-is) processes and customer journeys are modelled. Touchpoints are established and act as a “bridge” between the internal (business process) and external (customer journey) models.
  3. **Process and customer experience analysis**. Internal processes and customer experience are analysed, with an emphasis on the link or the indication of an impact the individual internal processes have on forming a positive or negative customer experience.
  4. **Process and customer experience redesign**. Based on the previous (analysis) phase, redesign of the as-is business processes and customer journeys is conducted.
  5. **Process implementation.** Redesigned processes are implemented within the organization, which can include changes in process, organizational or technological segments. These all have an impact on the journey of the customer.
  6. **Process and customer experience monitoring and control.** Business process and customer experience key performance indicators are monitored on a continuous basis in order to be able to evaluate the impact and the results of the implemented changes.

As elaborated by Pavlic and Cukusic (2019b), below are the relevant models created within ARIS tools in order to enable BPM-CXM operationalization:

1. **Entry-level model**. Other than the traditional entry model elements proposed by AVE methodology (Scheer, 2000), new model contains an individual quadrant for the customer experience landscape. Equal importance is given from the entry level perspective to both internal processes and external customer experiences.

Graphical user interface, application, website, Teams

Description automatically generated

Figure 2. *BPM-CXM entry model* (Pavlic and Cukusic, 2019b; Pavlic, 2021)

Customer Journey Landscape. This model type encompasses a more detailed overview of the customer’s perspective: it visualizes customer lifecycle stage(s) with the underlaying customer journeys. Overall customer experience attribute is calculated and monitored on the lifecycle stage as well as journey level. Objects of the model are represented in specific colours to indicate the customer experience levels.

Diagram

Description automatically generated

Figure 3. *BPM-CXM customer lifecycle stage model* (Pavlic and Cukusic, 2019b; Pavlic, 2021)

**Customer Journey Map.** This model visualises an entire end-to-end journey of the customer, with the underlaying journey steps before, during and after an interaction with the organization. It contains different objects relevant to the journey of the customer: customer journey steps, touchpoints, channels, information carriers (inputs/outputs), risks, key performance indicators, improvement initiatives, functional ownership (org. units or positions), and internal process functions.

Graphical user interface

Description automatically generated

Figure 4. *BPM-CXM customer journey map* (Pavlic and Cukusic, 2019b; Pavlic, 2021)

Within the model, Overall customer experience indictation is represented on the end-to-end basis as an attribute of the model. It is calculated by taking into the account the importance for the customer and customer feeling of each touchpoint of the journey. The data can be produced as a part of research, based on the existing KPIs, or reused from the existing IT systems. Each touchpoint can optionally be a pain point, moment of truth, and/or best practice.

**Customer Touchpoint Allocation Diagram.** This model is used for further detailing and analyzing all the aspects of a customer touchpoint. Similar to the customer journey map (however now on an individual touchpoint level), the objects that the model contains are: customer journey steps, internal process functions, positions (that represent the ownership of the touchpoint from an internal organization perspective), channels, risks, information carriers (inputs/outputs), key performance indicators, and improvement initiatives. Each of these elements can be further described by using the system or customized attributes.

Graphical user interface

Description automatically generated

Figure 5. *BPM-CXM customer touchpoint allocation diagram* (Pavlic and Cukusic, 2019b; Pavlic, 2021)

**Value-added Chain Diagram.** This model shows a high level process perspective. The important addition of the BPM-CXM approach is that this model includes an indication of the overall customer experience impact generated by each individual process, which is calculated as an average of the customer experience of all the associated touchpoints of a particular process. It also provides an overview of the underlaying touchpoints (with customer experience indication for each touchpoint) for each segment of the end-ot-end process. Based on that, indications are provided on which internal processes should be optimized to improve the experience of the customer.

Diagram

Description automatically generated

Figure 6. *BPM-CXM value-added chain diagram (with touchpoint representation)* (Pavlic and Cukusic, 2019b; Pavlic, 2021)

**Event-Driven Process Chain.** This model shows internal processes and their manual or system activities on a detailed level. In addition to the internal process steps and the associated inputs/outputs, organizational units, IT systems and risks, they also contain touchpoints with the customers. Touchpoints form a “bridge” between a customer and the organization, and they include a colour indication of the overall customer experience.

Diagram

Description automatically generated

Figure 7. *BPM-CXM process model (with touchpoint representation)* (Pavlic and Cukusic, 2019b; Pavlic, 2021)

CONCLUSION

The BPM-CXM convergent approach establishes a synergy between the BPM and CXM strategic approaches. Considering that the process is as good as its weakest point, it is important to continuously improve end-to-end processes. While doing so, it is crucial to take into account not only the internal, but also the external perspective – or the needs of the customers (in the local government case, citizens) external to the organization, as well as the touchpoints connecting these two perspectives. In order to truly become citizen oriented, local governments should fully understand the needs as well as processes from the perspective of citizens – and design their internal processes in a way to optimize and support them. This should be a prerequisite for designing and introducing any smart city related services. As such, it should enable the local governments to redesign the current services and transition to a smart mode of operation within the 4 crucial segments: process, organizational, technological, and citizen-experience.

According to the gap recognised by Rosenbaum and others (2017), BPM-CXM approach enables detection and the analysis of touchpoints between the internal organization and the customer, as well as directing value that the organization generates towards the customer. The approach recognizes customer journey as one of the processes which the organizations should manage, and continuously align with other processes. As a methodological approach for the analysis and the evaluation of impact of business processes transformation on the customer journey and vice versa, it is useful since it provides valuable information to be considered along the unavoidable business and IT transformation. By using the proposed approach, a solid baseline architecture for understanding the needs of citizens as well as connecting them with the internal processes would be established. Communication and general interaction between the process management and customer experience departments would no longer be kept in silos. Better alignment between the internal process design and needs of the citizens would be enabled. Satisfaction of internal employees of the organization, as well as customers, should be improved by making their experience seamless through smart city enabled services.

In addition, by using the proposed approach, fulfilment of the needs of customers is evaluated within the internal processes management context. This enables added value for the customers, higher positive customer experience, better communication and transparency, and better alignment of key performance indicators between the departments. Based on that, BPM-CXM approach can eliminate a lot of issues within the traditional approaches which are related to smart city transformations. It should align the internal and external project goals, which should also lead the the higher success rate of the projects. It should also improve the organizational performance and customer experience in general. Compared to the traditional approaches, it should result in internal process improvements in parallel with increasing the satisfaction of customers. Therefore, it is evident that it is no longer possible to transform the internal processes of the organization, without taking into account the interactions with the customer. Even though BPM and CXM were not very well-connected domains in the past, benefits of the convergent approach are significant not only within the mentioned domains, but for the entire organization as well. Only when the initiatives for the smart city services are aligned with the needs of the customer, transformation potential can be fully used.

Challenges of the implementation of BPM-CXM approach also exist. While citizen involvement can be a meaningful instrument, considering the nature of their goals which can be misaligned with the organizational strategy, it might not primarily contribute to process optimization in economic terms (Niehaves and Malsch, 2009). Furthermore, it is always a challenge to change the existing organizational structures for whatever reason. The approach requires openness of employees towards change, which is sometimes the most significant challenge within the organization. It is relatively complex and requires strong support from the management of the organization. It also requires good cooperation of all the stakeholders during the implementation. This is relevant for the process, organizational and technological aspect. Stakeholders should also have a clear understanding of the goals and benefits of the approach in order to minimize the eventual resistance to change, that could have negative implications on the overall smart city implementation journey.

REFERENCES

1. Alt, R., Puschmann, T. (2005). Developing customer process orientation: the case of Pharma Corp. *Business Process Management Journal*, 11(4), pp. 297–315.
2. Becker, J., Niehaves, B., Malsbender, A., Ortbach, K., Plattfault, R., Pöppelbuß, J. (2011). Taking a BPM Lifecycle View on Service Productivity: Results from a Literature Analysis. *Proceedings of the 11th International RESER Conference*, pp. 1–20.
3. Bergh, J. Van den, Thijs, S., Viaene, S. (2014). *Transforming Through Processes Leading Voices on BPM, People and Technology*. London: Springer International Publishing.
4. Bernardo, R., Galvina, S. V. R., de Pádua, S. I. D. (2017) The BPM lifecycle: How to incorporate a view external to the organization through dynamic capability. *Business Process Management Journal*, 23(1), pp. 155–157.
5. Bolton, M. (2004). Customer centric business processing. *International Journal of Productivity and Performance Management*, 53(1), pp. 44–51. doi: 10.1108/17410400410509950.
6. Botha, G. J., Kruger, P. S., de Vries, M. (2012). Enhancing customer experience through business process improvement: An application of the enhanced customer experience framework (ECEF). *South African Journal of Industrial Engineering*, 23(1), pp. 39–56. doi: 10.7166/23-1-218.
7. Botha, G. J., Rensburg, A. C. van (2010). Proposed Business Process Improvement Model With Integrated Customer Experience Management. *South African Journal of Industrial Engineering*, 21(1), pp. 45–57.
8. Brocke, H., Uebernickel, F., Brenner, W. (2010). A methodical procedure for designing consumer oriented on-demand IT service propositions. *Information Systems and e-Business Management*, 9(2), pp. 283–302. doi: 10.1007/s10257-010-0147-z.
9. vom Brocke, J., Rosemann, M. (2010). The Six Core Elements of Business Process Management. In: Vom Brocke, J. and Rosemann, M. (eds). *Handbook on Business Process Management 1*. Springer Heidelberg Dordrecht London New York, p. 622.
10. Chen, H., Daugherty, P. J., Landry, T. D. (2009). Supply chain process integration: A theoretical framework. *Journal of Business Logistics*, 30(2), pp. 27–46.
11. City of Zagreb (2018). Integrated Action Plan City of Zagreb. SmartImpact: City of Zagreb IAP, (May).
12. Davis, R. (2011). It’s the Customer Journey That Counts. *A BPTrends Column*, pp. 1–5.
13. Dumas, M., La Rosa, M., Mendling, J., Reijers, H. A. (2018). *Fundamentals of business process management*. Berlin: Springer-Verlag Berlin Heidelberg.
14. Esfahani, M. D., Rahman, A. A., Zakaria, N. H. (2013). Customer Oriented Business Process Improvement Metodology for Public Sector Organizations. *Proceedings - Pacific Asia Conference on Information Systems*.
15. Flint, D. J., Larsson, E., Gammelgaard, B., Mentzer, J. T. (2005). Logistics innovation: A customer value-oriented social process. *Journal of Business Logistics*, 26(1), pp. 113–147.
16. Frank, L., Poll, R., Röglinger, M., Rupprecht, L. (2020). Design heuristics for customer-centric business processes. *Business Process Management Journal*, 26(6), pp. 1283–1305. doi: 10.1108/BPMJ-06-2019-0257.
17. Gersch, M., Hewing, M., Schöler, B. (2011). Business Process Blueprinting – an enhanced view on process performance. *Business Process Management Journal*, 17(5), pp. 732–747.
18. Gloppen, J., Lindquister, B., Daae, H.-P. (2016). The customer journey as a tool for business innovation and transformation. In: DeFillippi, R., Rieple, A., Wikström, P. (eds). *International Perspectives on Business Innovation and Disruption in Design*, pp. 118–136.
19. Gustafsson, A., Johnson, M. D. (2006). Improving Customer Satisfaction, Loyalty, and Profit: An Integrated Measurement and Management System’, John Wiley & Sons.
20. Heckl, D., Moormann, J. (2007). Matching customer processes with business processes of banks: The example of small and medium-sized enterprises as bank customers. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 4714 LNCS, pp. 112–124. doi: 10.1007/978-3-540-75183-0\_9.
21. Van Hee, K. M., Reijers, H. A. (2000). Using Formal Analysis Techniques in Business Process Redesign. *Business Process Management*, pp. 142–160. doi: 10.1007/3-540-45594-9\_10.
22. Helmy, Y. M., Abdelgaber, S., Fahmy, H., Montasser, H.S. (2020). A conceptual ontological framework for managing the social business process to enhance customer experience. *Knowledge and Process Management*, 27(4), pp. 262–271. doi: 10.1002/kpm.1652.
23. Jeet, V. (2017). Convergence of IoT and BPM for Smarter Cities. DQINDIA ONLINE.
24. Johnston, R., Kong, X. (2011). The Customer Experience : A Road Map for Improvement. *Managing Service Quality*, 21(1), pp. 5–24.
25. Kaplan, R. S., Norton, D. P. (1996). Linking the Balanced Scorecard to Strategy. *California Management Review*, 39(1).
26. Kapulin, D. V., Russkikh, P. A., Moor, I. A. (2019). Integration capabilities of business process models and ERP-systems. *Journal of Physics: Conference Series*, 1333(7). doi: 10.1088/1742-6596/1333/7/072009.
27. Klose, K., Knackstedt, R., Becker, J. (2005). Process modelling for service processes: Modelling methods extensions for specifying and analysing customer integration. *ICEIS 2005 - Proceedings of the 7th International Conference on Enterprise Information Systems*, pp. 260–265. doi: 10.5220/0002534202600265.
28. Kohlbacher, M., Weitlaner, D. (2011). Process cascade- and segmentation-based organizational design: A case study. *IEEE International Conference on Industrial Engineering and Engineering Management*, pp. 1343–1347. doi: 10.1109/IEEM.2011.6118135.
29. Kreuzer, T., Röglinger, M., Rupprecht, L. (2020). Customer-centric prioritization of process improvement projects. *Decision Support Systems*, 133. doi: 10.1016/j.dss.2020.113286.
30. Kumar, V., Smart, P.A., Maddern, H., Maull, R.S. (2008). Alternative perspectives on service quality and customer satisfaction: the role of BPM. *International Journal of Service Industry Management*, 19(2), pp. 176–187.
31. Lee, C.-H., Huang, S. Y., Barnes, F. B., Kao, Li. (2010). Business performance and customer relationship management: The effect of IT, organisational contingency and business process on Taiwanese manufacturers. *Total Quality Management & Business Excellence*, 21(1), pp. 43–65.
32. Lee, E., Karahasanović, A. (2013). Can Business Process Management Benefit from Service Journey Modelling Language?. *ICSEA 2013, The Eighth International Conference on Software Engineering Advances*, (c), pp. 579–582.
33. Margaria, T., Boßelmann, S., Doedt, M., Floyd, B. D., Steffen, B. (2012). Customer-Oriented Business Process Management: Vision and Obstacles. *Conquering Complexity*, pp. 1–466. doi: 10.1007/978-1-4471-2297-5.
34. Mendling, J., Decker, G., Hull, R., Reijers, H. A., Weber, I. (2018). How do machine learning, robotic process automation, and blockchains affect the human factor in business process management?. *Communications of the Association for Information Systems*, 43(1). pp. 297–320, doi: 10.17705/1CAIS.04319.
35. Meyer, C., Schwager, A. (2007). Understanding Customer Experience. *Harvard Business Review*, pp. 116–124.
36. Moormann, J., Palvolgyi, E. Z. (2013). Customer-Centric Business Modeling: Setting a Research Agenda. *2013 IEEE 15th Conference on Business Informatics*, pp. 173–179.
37. Neubauer, T. (2009). An empirical study about the status of business process management. *Business Process Management Journal*, 15(2), pp. 166–183.
38. Niehaves, B., Malsch, R. (2009). Democratizing process innovation? On citizen involvement in public sector BPM. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 5693 LNCS, pp. 245–256. doi: 10.1007/978-3-642-03516-6\_21.
39. Niehaves, B., Plattfaut, R. (2010). From bureaucratic to quasi-market environments: On the co-evolution of public sector business process management. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 6228 LNCS, pp. 387–399. doi: 10.1007/978-3-642-14799-9\_33.
40. Norton, D. W., Pine II, B. J. (2013). Using the customer journey to road test and refine the business model. *Strategy & Leadership*, 41(2), pp. 12–17.
41. Osman, C. C., Ghiran, A. M. (2019). Extracting Customer Traces from CRMS: From Software to Process Models. *Procedia Manufacturing, 32*, pp. 619–626. doi: 10.1016/j.promfg.2019.02.261.
42. Pavlic, D. (2021). *Business Process Management and Customer Experience Management Convergence Model*. Faculty of Economics, University of Split.
43. Pavlic, D., Cukusic, M. (2019a). *Developing a structured approach to converging business process management and customer experience management initiatives. Lecture Notes in Business Information Processing*. doi: 10.1007/978-3-030-35151-9\_10.
44. Pavlic, D., Cukusic, M. (2019b). Developing a Structured Approach to Converging Business Process Management and Customer Experience Management Initiatives. In: Gordijn, J., Guédria, W., Proper, H. A. (eds). *The Practice of Enterprise Modeling Developing*. Springer Nature Switzerland AG.
45. Payne, A., Frow, P. (2005). A Strategic Framework for Customer Relationship Management. *Journal of Marketing*, 69(4), pp. 167–176.
46. Rajala, M., Savolainen, T. (1996). A framework for customer oriented business process modelling. *Computer Integrated Manufacturing Systems*, 9(3), pp. 127–135.
47. Richardson, C. (2016). End of the Road for End-to-End Process Transformation, Blog by Business Process Management, Inc. Available at: http://bpm.com/bpm-today/blogs/1136-end-of-the-road-for-end-to-end-process-transformation (Accessed: 26 April 2017).
48. Rosemann, M. (2014). Proposals for future BPM research directions. *Lecture Notes in Business Information Processing*, 181 LNBIP, pp. 1–15. doi: 10.1007/978-3-319-08222-6.
49. Rosenbaum, M. S., Otalora, M. L., Contreras Ramírez, G. (2017). How to create a realistic customer journey map. *Business Horizons*, 60(1).
50. Ruland, Y. (2016). Customer experience and its potential to extend business process management. *Master thesis - FACULTEIT BEDRIJFSECONOMISCHE WETENSCHAPPEN*, p. 85.
51. Scheer, A.-W. (2000). ARIS — Business Process Modeling. 3rd edn, *Journal of Chemical Information and Modeling*. 3rd edn. Berlin: Springer-Verlag Berlin Heidelberg.
52. Scheer, A. W., Jost, W., Heß, H., Kronz, A. (2005). *Corporate performance management*. Springer-Verlag Berlin Heidelberg.
53. Schmiedel, T., Vom Brocke, J., Recker, J. (2014). Development and validation of an instrument to measure organizational cultures’ support of Business Process Management. *Information and Management*, 51(1), pp. 43–56.
54. Schmitt, B. H. (2003). *Customer experience management: A revolutionary approach to connecting with your customers*. New Jersey: John Wiley & Sons, Inc.
55. Schmitt, B. H. (2010). Experience Marketing: Concepts, Frameworks and Consumer Insights. *Foundations and Trends® in Marketing*, 5(2), pp. 55–112.
56. Temkin, B. D. (2010). Mapping The Customer Journey. *Forrester Research*.
57. Trkman, P., Mertens, W., Viaene, S., Gemmel, P. (2015). From business process management to customer process management. *Business Process Management Journal*, 21(2), pp. 250–266.
58. Vanwersch, R. J. B., Shajhzad, K., Vanderfeesten, I., Vanhaecht, K., Grefen, P., Pintelon, L., Mendling, J., van Merode G. G., Reijers, H. A. (2015). A Critical Evaluation and Framework of Business Process Improvement Methods. *Business & Information Systems Engineering*, 58(1), pp. 1–11.
59. Vidovic, S. (2015). Smart City: From strategic planning to intelligent applications and agile systems. *DaNTe Conference*.
60. Voorhees, C. M., Fombelle, P. W., Gregoire, Y., Bone, S., Gustafsson, A., Sousa, R., Walkowiak, T. (2017). Service encounters, experiences and the customer journey: Defining the field and a call to expand our lens. *Journal of Business Research*, 79 (November 2016), pp. 269–280.

**ATTITUDE TOWARDS SMART CITY’S ELEMENTS – SELECTED TRENDS AND A COMPARATIVE STUDY BETWEEN DIFFERENT RESIDENTS**

INTRODUCTION

The urban population has been rising by 65 million people a year on average. It indicates the highest level of urbanization in history, but as it grows, the environmental pressures intensify as well. The increasing population density in urban areas causes numerous environmental issues. The concerns about sustainability are constantly rising and that is another reason for why a smart environment is highly relevant and should be further addressed. There are several three major trends within the smart environment such as air-quality monitoring, energy-use optimization, and waste reduction. Smart solutions in these fields are extremely promising as their implementation is expected to result in 10-15% fewer greenhouse gas emissions and 30-130 fewer kilograms of solid waste per person per year (Woetzel et al., 2018).

When visualising a smart city the image that appears is a city that can offer its citizens a high quality of life by using resources in a sustainable way, through the implementation of innovative technologies. The term smart city does not have a single and specific definition. Since its first introduction as a concept in Silicon Valley, it has been widely used and applied in different contexts, thus, carrying different meanings (Lindskog, 2004). The general concept of a smart city revolves around the combination of studies in urbanism and information and communication technologies with some aspects of creativity and participation in society. It involves the reorganization of the city structure and the improvement of the living conditions of its citizens. It usually requires the use of technological tools, such as the internet of things or artificial intelligence; however, it is also based on the collaboration between governments and different departments of society and involves changes to the contemplative side of the society (Ruohomaa, Salminen, & Kunttu, 2019).

In order to facilitate the transition to a smarter city, there are several factors that need to be changed before beginning the improvements. The roles of each contributor should be specified, in order to stimulate collaboration between all departments. The citizens should not only cover the role of the observer but rather collaborate in the process and actively participate by involving innovative thinking. Organizations should also transform their roles, from providers to a partners that are willing to collaborate on the development of the city. Smart cities should not only be focused on the digitalization of the city services but also on supporting the process of transformation by involving society departments, governance, and collaboration between city stakeholders (Vanolo, 2014).

CHARACTERISTICS OF SMART CITIES

There are different characteristics which a smart city can consist of, like smart economy, smart people, smart governance, smart mobility, smart environment, and smart living (Capdevila & Zarlenga, 2015). For each of these areas, the literature provides several possible definitions.

Smart economy primarily revolves around effectively allocating economic resources (Apostol, Balaceanu, & Constantinescu, 2015), while dynamically adapting to current situations. The allocation of economic resources refers to a monitoring process that controls how wealth is created and distributed within the economy. The main idea behind a smart economy is to reduce modern social problems related to poverty, hunger, inequality of opportunity and others. A successfully implemented smart economy concept can help individuals choose on how to earn and use their income, ultimately improving the quality of life of the individual, but also reducing unemployment levels within the society.

The definitions in the area of smart people mainly focus on the inclusion of citizens in the development process of the smart city itself. Smart cities are cities consisting of smart people, who can positively influence the community through their creativity (Capdevila & Zarlenga, 2015). Additionally, smart cities should not only focus on developing the technologies used, but rather educate their citizens on how to use these technologies (Lacinák & Ristvej, 2017). Nevertheless, even the most cutting-edge Smart City failed to achieve its purpose, if the features of Smart Citizen are missing.

Smart governance revolves around smart cities allowing for smart collaboration. For the city governments, this affects both the institutions’ governance and the institutions’ policy. Smart governance can thus be defined as (Israilidis, Odusanya, & Mazhar, 2021) the process of not only citizens being involved in the city’s governance process, but also other public, private and civic stakeholders. Smart governance builds on all these players collaborating and innovating together, creating an interconnected society (Haque, Bhushan, & Dhiman, 2021). In a survey conducted by the EU commission, 63% of the EU citizens would like to have a digital ID. This would enable them easy access to governmental procedures like tax filing, or other public services. It would also allow EU citizens the opportunity to easily use public service providers in another country.

3

Smart mobility is a rather straightforward term and addresses the increase in traffic in cities all around the world. Moreover, by reducing traffic, it can also have a positive effect on the environment, by reducing pollution. Smart Mobility within smart cities therefore tackles concerns regarding travel time, energy efficiency, and environmental issues. One clear-cut trend in Smart Mobility is the use of autonomous mobility. Although still in a very early development stage, autonomous vehicles seem to be a possible solution for the previously mentioned problems smart mobility is trying to address (Manfreda, Ljubi, & Groznik, 2021). Another trend in the area of smart mobility is car sharing. In 2015, the number of worldwide users was at 7 million, but this is expected to increase dramatically, up to 36 million users in 2025.

The area of smart environment deals with improving sustainability aspects of the city. The use of technology is supposed to create a sustainable living environment, whilst utilizing natural and economic resources more efficiently (Haque, et al., 2021). The sustainability approach allows for the development of a sustainable health care system and inspires a greener lifestyle. One trend in this area is the implementation of so-called Smart Ports. By changing the infrastructure of industrial ports, it is possible to not only improve the economic efficiencies, but it is also possible to reduce the negative effects on the environment. The Smart Port initiative in Rotterdam, Netherlands, aims at becoming a “renewable energy hub” and a “recycling hub”.

Smart living tackles all aspects dealing with the quality of life of each individual citizen. The term “quality of life” can be seen in various definitions. Improving quality of life is such a broad term, it allows for many interpretations. Generally, smart cities use ICTs to improve the quality of life of its citizens (Capdevila & Zarlenga, 2015). Important factors contributing to quality of life are education, health, and safety, and social cohesion and touristic attractively as well (Giffinger, Fertner, Kramar, & Meijers, 2007).

DEVELOPMENT STAGES OF SMART CITIES

Cities according to their level of "smartness" are placed in five or six phases or generations (six if also cities without any of the characteristics of smart cities are included). The city moves upwards in stages, depending on its way of adopting new technologies and developments. The phases can be divided as (Khan, Aslam, Aurangzeb, Alhussein, & Javaid, 2022):

* Smart City 1.0: Development is driven solely by technological advances, but greater ones technology companies with many resources and influence, such as Google, IBM and CISCO. Criticism of the first phase of smart cities is mainly in the imposition of technology and the great impact that it is held by technology companies because of their position.
* Smart City 2.0: The second phase of the smart city is also driven by technological progress, however, this one, unlike the first one, is aimed precisely at solving specific problems of the cities such as pollution, cleaning, health and transport. Problems are addressed and solved in cooperation with the residents, and their involvement is due to poor organizational structures still small.
* Smart City 3.0: The third phase of a smart city is driven by the expectations of residents or users. A smart city thus represents the whole connected ecosystem, which brings together technologies, solutions, actors (management, strategists, solution providers) and users (residents) of the city including the IoT (Internet of things), 5G connectivity, transport, smart mobility, energy and public services, health and public safety, artificial intelligence and data analytics.
* Smart City 4.0: With the Industrial revolution 4.0, the positive effects of smart cities are expected finally exceeded their costs. Smart City 4.0 brings together all the best properties of previous phases (technological disruption 1.0, individualization 2.0 and inclusion 3.0), but adds two key success factors: an integrated approach and problem solving of integration of different solutions. An integrated approach aims to integrate new technologies with old ones, and also includes the possibility of integrating with solutions not developed yet. Municipality management is well aware of the opportunities and limitations of new technologies and the overall impact that smart city technologies can have on their community. Self-awareness is still widespread in terms of influencing certain residents of the community, as not everyone feels the same positive effects.
* Smart City 5.0: The last phase of smart cities is dominated by artificial intelligence, namely cooperation between people and artificial intelligence systems. Its approach allows for consensus between different services and residents. Past and current events are constantly identified and analysed, which is then translated into plans, implementations and supervisions.

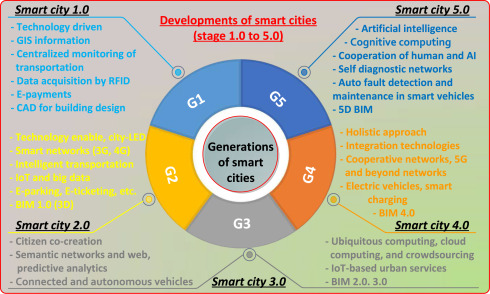


Figure 1: Stages of smart city development (Khan, et al., 2022)

CHALLENGES RELATED TO SMART CITIES

It becomes clear that a lot of challenges revolve around data security issues. Deloitte in 2015 reported that the technology used within smart cities requires a massive amount of data. Consequently, the question on how to deal with this data appropriately comes up. In a study conducted by Manfreda et al. (Manfreda, et al., 2021), data security issues appeared to be very high. These potential privacy issues range from the citizens giving away confidential information unwillingly, users being monitored through their various activities, or even users not being able to access the system at all (Haque, et al., 2021). As currently most devices used for the implementation of smart solutions rely on third-party services, there is a great chance of hackers entering the system, spreading malware or feeding the system with wrong data. In the case of a large cyber-attack on a smart city, a well interconnected city might lose control over a lot of processes within its whole infrastructure (Haque, et al., 2021).

Adter all, big data offers cities the opportunity to gain valuable insights from the vast amount of data collected through a variety of sources, and the Internet of Things allows the integration of sensors in a real environment using high-network services. The combination of the Internet of Things and big data is an unexplored field of research that has brought new and exciting challenges to achieving the goal of future smart cities. These new challenges focus primarily on business and technology issues that enable cities to realize the vision, principles, and requirements of smart city applications by realizing the key features of a smart environment (Hashem et al., 2016).

More generally, smart cities rely on the citizens actually using the provided solutions. The adoption of new technologies is highly dependable on the potential users’ belief that the solution is actually useful (Manfreda, et al., 2021). Thus, there is an important question, if implemented solutions are really useful to the user, or if the solution solely feeds corporate interests (Calzada & Cobo, 2015). This aspect cannot be highlighted enough, as the best solution is worthless if the users are not using it. Therefore, user-friendliness appears to be one of the most important aspects when creating a smart city solution. Additionally, one has to think about citizens who are not able to use technological devices or smart solutions in general. In their report from 2015, Deloitte describes this aspect as the potential of widening the gap between citizens, because some citizens might be “left behind” resulting from their low internet access or “digital savviness”.

SELECTED TRENDS AND ISSUES

## Waste-reduction solutions

Before industrialization and globalization processes started, solid waste did not pose a significant threat as the rate of its disposal per capita was incomparable to the contemporary levels. However, consequently, it has become an extensive problem due to the continuous growth of the population and the corresponding amount of waste generated. In particular, the amount of food waste worldwide is roughly equivalent to 1.3 billion tons, which is enough to feed 3 billion people. Comparing it to the 690 million people who suffer from malnutrition nowadays, we can clearly see that the situation can be significantly improved by the implementation of corresponding smart solutions.

Some cities have managed to reduce the volume of solid waste generated by implementing effective recycling programs, but these programs have certain limitations. That is why existing waste management infrastructures for waste collection, segregation, transportation, and final disposal can be improved through the integration of smart city technologies such as the internet of things, artificial intelligence, cloud computing, and intelligent transportation systems with the existing waste management system and infrastructure for waste collection, segregation, transportation, treatment, and final disposal (Shukla & Hait, 2022).

As a first solution, digital tracking and payment for waste disposal can potentially enable the city to charge citizens for the exact amount and type of trash they throw away. This practice is widely considered nowadays and detailed plans for its implementation are already established in some UK cities. The pay-as-you-throw system helps reduce the amount of unrecycled municipal solid waste generated per capita by 10–20 percent, while detailed insights from tracking increases awareness and motivates users to reduce waste. Basically, it prevents people from throwing away items without a need and encourages them to reduce the amount of waste generated in general (Woetzel, et al., 2018).

Another approach to the waste collection is used to optimize the process and to stop people from dumping waste in the containers meant for other categories of waste or simply on a street next to the full ones. This is achieved through the sensors inside trash bins to measure the current volume and timely direct the trucks to locations where they are needed. It does not only enforce the waste collection but also decreases the amount of energy consumed during the collection, which leads us to the next trend (Woetzel, et al., 2018).

## Energy-use optimization

Since urbanization is continuously growing cities require more and more energy. As a result, urban areas consume over two-thirds of the world’s energy and generate around 70 percent of its greenhouse gas emissions. Although energy consumption is a complex problem, it can be reduced through the integration of interconnected smart solutions that address the issue from multiple perspectives for the most effective results. The implementation of automated systems with smart meters and grids in commercial buildings and private households significantly optimize energy consumption as sensors collect the data for the analytics of existing inefficiencies, while grids minimize energy losses in transmission and distribution stages. Only in 2019, 123 billion U.S. dollars were spent on smart grids, while smart meter investments amounted to 21 billion U.S. dollars (Alves, 2022).

In addition, dynamic electricity pricing can be implemented through smart meters that record the consumption of energy and communicate this data to the suppliers. The collected data can be used for price differentiation based on the season and the time of day. This approach is supposed to encourage end-users to be more responsive and efficient since all the information on their consumption and prices is visible in the responsive mobile apps. However, the savings are not expected to be significant for private households. Therefore, optimization could be further encouraged through various aspects to make consumers more aware of their energy usage and influence them to change their behavior to decrease their energy consumption, while the increased efficiency of the energy delivery by smart grids also decreases the costs and creates an incentive for lower consumption (Woetzel, et al., 2018).

As the need and will for electric vehicles rises, and consumers start using these more, the need for charging infrastructure also increases. Even though consumers are mainly shifting to EV from environmental and economic benefits’ perspective, there are some factors that are still limiting the non-EV users to purchase one such as the fear that the battery will drain before someone reaches the destination, lack of charging stations, long charging times. This is why it is expected that cities will have to act on this by setting up more charging stations in places where the frequency of people is high.

## Air-quality monitoring

The problem of air pollution is also extremely relevant nowadays. It is not surprising that many smart cities pay great attention to this issue and implement different solutions to overcome it. The increasing rate of CO2 emissions is the biggest concern in this field as it directly contributes to global warming. Many cities have developed certain strategies for the reduction of CO2 emissions, while some of them even plan to reach zero-emission levels in the nearest future. Some measures are taken on a bigger level, for example, to cut carbon emissions by at least 55 percent by the year 2030, compared with the levels in 1990 (European Commission, 2021).

Thus, it is crucial to detect and monitor the level of pollution. It helps to identify the most problematic areas and potential causes, hence, effectively implementing necessary preventive solutions. In addition, the progress can be easily tracked like this. In order to monitor air pollution, smart cities implement various technologies including IoT, integrating low-cost sensors, satellite data, and data mining tools. Some countries use vehicles that are equipped with special detectors which analyse the air for various types of emissions. Consequently, based on the acquired data, the pollution maps are composed. Mobile sensors are also gaining popularity in source estimation, health exposure assessment, and creating awareness regarding the problem (Kaginalkar, Kumar, Gargava, & Niyogi, 2021).

However, awareness does not resolve the issue on its own. The data collected through the integrated technologies merely enables the city to make objective and informed decisions to improve the situation.

RESEARCH METHODOLOGY

To address the research question regarding how smart city services are perceived among general population in Slovenia and Croatia, a sample of 1.390 Slovenian and Croatian residents was analysed. Data collection was performed using an online survey tool. Data were collected over the course of ten months from June 2020 to March 2021. Altogether, 1390 individuals completed the survey with the necessary data for the analysis, while 2.937 individuals received the questionnaire. Descriptive statistics and mean comparisons were used for examination of differences between perceptions of smart city services between Slovene and Croatian residents.

DATA ANALYSIS

The sample includes 1390 respondents from Slovenia and Croatia that are mostly university students between 21 and 30 years living in urban settlements (see table 1).

Table 1. Profile of the respondents.

|  | | **Share (%)** |
| --- | --- | --- |
| **Gender** | Male | 37.4 |
| Female | 62.6 |
| **Status** | High school student | 0.1 |
| Student | 78.7 |
| Employed person | 17.5 |
| Self-employed person | 0.6 |
| Unemployed | 0.6 |
| Retired | 2.4 |
| Graduate | 10.7 |
| **Age** | Under 20 | 30.5 |
|  | 21 – 30 | 51.1 |
|  | 31 - 40 | 6.9 |
|  | 41 – 50 | 5.9 |
|  | 51 – 60 | 2.7 |
|  | Above 60 | 2.8 |
| **Highest level of formal education** | Primary school | 0.4 |
|  | High school (4 years) | 55.8 |
|  | Undergraduate programme/university (3 years) | 24.6 |
|  | Graduate programme (2 years) | 10.5 |
|  | Doctoral programme (PhD) | 8.7 |
| **Type of settlement** | Urban settlement | 62.0 |
| Suburban settlement | 20.0 |
| Small town or village | 13.5 |
| Scattered or secluded houses | 4.5 |
| **Country of residence** | Slovenia | 45.7 |
| Croatia | 54.3 |

First, a descriptive analysis of arithmetic means was conducted on the whole sample, followed up by a comparison of means between Slovene and Croatian residents. The topics of analysis were related to their perception of technology and the smart city concept in general, as well as to more specific smart city related issues, such as security and privacy issues, environmental issues, smart mobility, smart healthcare, and the citizen participation in the development of smart city services. Responses were mostly measured on a 5-point scale, where 1 means the respondent strongly disagrees with the statement mentioned and 5 means the respondent strongly agrees with it.

In the next paragraphs, we are going to present the results of the survey, divided into the following sections: technology interest, smart city, security and privacy in smart cities, smart mobility, environmental issues with smart cities (together with the ‘influence on environmental issues on individual behaviour’ and ‘privacy issues within air pollution sensors and energy consumption sensors’), waste pollution, noise pollution, and light pollution.

TECHNOLOGY INTEREST

Regarding technology interest, on average all respondents agree that new technologies are contributing to a higher standard of living. They are neutral about their use of new technologies, meaning they are not too eager to experiment with them as soon as possible on one hand, while on the other they are also not hesitant to use them or wait for them to become accepted by the general public. Slovenes are waiting less than Croats for technology to become generally accepted, whereas they are similar in other aspects of technology interest.

|  |  |  |  |
| --- | --- | --- | --- |
| **Technology interest** | **Slovenia** | **Croatia** | **Total** |
| New technologies contribute to a higher standard of living | 4.3 | 4.1 | 4.2 |
| I am among the first to use new technologies and experiment with them soon after they become available | 2.9 | 3.1 | 3.0 |
| I am hesitant to use new technologies | 2.5 | 2.4 | 2.5 |
| I am waiting until new technology use becomes unavoidable and is accepted by the general public | 2.6 | 2.9 | 2.8 |

Moreover, all respondents on average agree that the modern world is too dependent on smart technologies (Croats a bit more than Slovenes), but at the same time want their job to be related to them and believe smart technologies could be applied to perform very complex tasks, such as planning, organizing, designing, optimizing resources, or managing things and people (Croats a bit more than Slovenes). They are neutral regarding their trust in smart technology capabilities for everyday decision-making processes.

|  |  |  |  |
| --- | --- | --- | --- |
| **Technology interest** | **Slovenia** | **Croatia** | **Total** |
| Modern world is too dependent on smart technologies | 3.5 | 3.9 | 3.7 |
| I fully trust smart technologies in everyday decision-making processes | 2.9 | 2.9 | 2.9 |
| Smart technologies could be applied to perform very complex tasks, e.g., planning, organizing, designing, optimizing resources, managing things and people | 3.6 | 4.0 | 3.8 |
| I want my job to be related to smart technologies | 3.6 | 3.6 | 3.6 |

**SMART CITY**

|  |  |  |  |
| --- | --- | --- | --- |
| **Smart city** | **Slovenia** | **Croatia** | **Total** |
| I am familiar with the concept of a smart city | 3.6 | 3.2 | 3.4 |
| I would be happy to use smart city services in my personal, social and professional life | 3.7 | 3.6 | 3.7 |
| I would prefer to live in the city that has no smart services | 2.4 | 2.6 | 2.5 |
| I am familiar with the initiatives that my local government is facilitating regarding smart city elements | 2.5 | 2.6 | 2.6 |
| I believe that smart city can improve the quality of life | 3.7 | 3.7 | 3.7 |
| I look forward to the widespread of smart cities | 3.5 | 3.6 | 3.5 |
| I look forward to living in a smart city | 3.5 | 3.5 | 3.5 |

Regarding the smart city in general, all respondents on average agree slightly that they are familiar with the smart city concept (Slovenes more than Croats), while they disagree slightly that they are familiar with initiatives of their local government on SC elements. They agree slightly that they would be happy to use SC services in their personal, social and professional life, and that smart cities can improve their quality of life and that they are looking forward to living in one. Moreover, they disagree slightly that they would prefer to live in a city without smart city services.

|  |  |  |  |
| --- | --- | --- | --- |
| **Smart city elements** | **Slovenia** | **Croatia** | **Total** |
| Smart public transportation | 4.2 | 4.2 | 4.2 |
| Smart parking system | 4.4 | 4.2 | 4.3 |
| Smart health care | 4.1 | 4.2 | 4.2 |
| Citizen-government interconnection | 3.8 | 4.1 | 4.0 |
| Smart street lightening | 4.4 | 4.2 | 4.3 |
| Smart waste disposal | 4.5 | 4.4 | 4.4 |

Regarding the distinct smart city elements, all respondents on average agree with all smart city elements being included in their city, such as smart public transportation, smart parking system, smart health care, smart street lightening, smart waste disposal and citizen government interconnection. They most strongly agree with smart waste disposal implementation.

|  |  |  |  |
| --- | --- | --- | --- |
| **Sensors and smart devices** | **Slovenia** | **Croatia** | **Total** |
| I do not mind installing appliances with internet-connected sensors in my home | 3.3 | 2.8 | 3.0 |
| I believe smart devices can make better decisions than humans | 3.0 | 2.5 | 2.7 |
| I would allow a smart device to make daily decision for me, e.g., organizing tasks, ordering food and clothes | 2.7 | 2.2 | 2.4 |
| I would allow a smart device to make an important decision for me, e.g., choosing a field of study, turning down a promotion | 1.9 | 1.9 | 1.9 |
| I would be willing to use robots not only at work but also in my everyday life | 3.1 | 2.4 | 2.7 |

Regarding sensors and smart devices use in smart cities, all respondents are on average neutral about installation of appliances with inter-connected sensors in their homes (Slovenes agree more than Croats). They disagree slightly that they would be willing to use robots at work, as well as in their daily life (Croats disagree more than Slovenes), since they believe that smart devices cannot make better decisions than humans (Slovenes agree more than Croats). They would prefer to use smart devices for daily decisions, such as organizing tasks or ordering food and clothes (Slovenes more than Croats), then for making important decisions, such as choosing a field of study or turning down a promotion, but they are not keen on using smart devices for either of these. To summarize, Croats are less keen on implementation and use of sensors and smart devices for work and in daily life. Besides that, Slovene and Croats disagree with the use of sensors and smart devices for making important decisions for them.

SECURITY AND PRIVACY IN SMART CITIES

|  |  |  |  |
| --- | --- | --- | --- |
| **Security and privacy in smart cities** | **Slovenia** | **Croatia** | **Total** |
| Data privacy | 4.2 | 4.1 | 4.2 |
| Security issues | 4.0 | 3.8 | 3.9 |
| Transparency of services | 3.1 | 3.4 | 3.3 |
| Complexity of services | 3.2 | 3.3 | 3.2 |
| Historical records of activities | 3.6 | 3.4 | 3.5 |
| The use of my data and preferences by other parties | 3.9 | 3.9 | 3.9 |
| Implementing 5G networks | 2.9 | 3.1 | 3.0 |
| Democracy, transparency and consideration of interests | 3.4 | 3.4 | 3.4 |

Regarding security and privacy issues in smart cities, all respondents are on average most concerned regarding data privacy issues, security issues, and the use of their data and preferences by other parties. They are neutral regarding the implementation of 5G networks, but otherwise agree there are security and privacy issues in smart cities. Nevertheless, they are not strongly concerned about it. There are no great differences between the perception of security and privacy between Slovenes and Croats.

SMART MOBILITY

|  |  |  |  |
| --- | --- | --- | --- |
| **Smart mobility** | **Slovenia** | **Croatia** | **Total** |
| I do not mind smart devices collecting and storing my data | 2.5 | 2.5 | 2.5 |
| I would be willing to share a larger amount of my data without the immediate expected mutual benefits | 2.1 | 2.3 | 2.2 |
| I would be willing to share a larger amount of my data if it meant raising the quality of life of the whole community | 3.1 | 3.0 | 3.0 |
| I would be willing to share a larger amount of my data if it meant a direct reduction in the cost of living, e.g., price of water, electricity, heating | 3.4 | 3.2 | 3.3 |
| I do not mind sharing information about my location | 2.3 | 2.4 | 2.3 |
| I believe the government should be allowed to collect all personal data about citizens | 1.9 | 2.3 | 2.1 |
| I trust agencies and companies to keep my data safe and not exploit it | 2.6 | 2.6 | 2.6 |

Regarding the smart mobility, all respondents on average disagree slightly with smart mobility related issues, such as data collection and storage by smart devices, especially if without an immediate exchange of benefits. They also disagree with sharing their location and other personal data, either to the government or to agencies and companies. They are neutral regarding data sharing for the benefit of their community and agree slightly with sharing data in exchange for the reduction of their cost of living. Slovenes and Croats are quite similar in their perception of smart mobility.

ENVIRONMENTAL ISSUES WITH SMART CITIES

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards sustainability** | **Slovenia** | **Croatia** | **Total** |
| I like the sustainable approach of smart cities | 4.1 | 3.7 | 3.8 |
| I live by sustainable principles | 3.7 | 3.5 | 3.6 |
| I try to pollute the environment as little as possible | 4.2 | 4.1 | 4.2 |
| I use reusable bags | 4.2 | 3.9 | 4.0 |
| I recycle waste | 4.3 | 3.7 | 3.9 |
| I try to avoid disposable products | 3.6 | 3.5 | 3.5 |

Regarding environmental issues with smart cities, all respondents on average like the sustainable approach of smart cities and agree that they are trying to minimize their environmental footprint by using reusable bags, recycling waste, etc. They are also trying to avoid disposable products and live by sustainable principles, but to a lower degree. Slovenes are in general slightly more sustainable-oriented than Croats, especially in recycling waste and use of reusable bags.

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards air pollution** | **Slovenia** | **Croatia** | **Total** |
| I am aware of the issue of air pollution | 4.4 | 4.2 | 4.3 |
| I am personally aware when air pollution is high | 3.7 | 3.8 | 3.8 |
| I believe it is my duty to the environment to reduce air pollution | 4.5 | 4.1 | 4.2 |
| I believe that my actions affect air pollution | 4.1 | 3.8 | 3.9 |
| I am aware that high levels of air pollution have an impact on human health | 4.5 | 4.3 | 4.4 |
| When I decide to buy a long-term useful item, I try to look for alternatives that can save on energy consumption | 3.5 | 3.6 | 3.5 |
| When I decide to buy a long-term useful item, I try to look for alternatives that contribute to sustainable development | 3.6 | 3.5 | 3.5 |

Regarding air pollution in smart cities, all respondents on average are well aware of the air pollution issue and its impact on human health. They sense quite well when air pollution is high. Moreover, they strongly believe that their actions affect air pollution and is therefore also their duty to reduce it. Nevertheless, they do not always decide to buy more sustainable long-term useful items or alternatives that save on environment consumption, although they do not disagree with it. Slovenes feel a slightly bigger obligation to the environment to reduce air pollution than Croats, but they are otherwise quite similar in their attitudes.

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ perception on the impact of smart cities on sustainability** | **Slovenia** | **Croatia** | **Total** |
| Smart cities help to prevent air pollution | 3.7 | 3.4 | 3.6 |
| Smart cities help to prevent climate change | 3.5 | 3.3 | 3.4 |
| Smart cities help to prevent excessive water use | 3.8 | 3.5 | 3.6 |
| Smart cities reduce energy consumption | 3.7 | 3.5 | 3.6 |

Regarding the smart city influence on sustainability, all respondents on average agree slightly that smart cities help to prevent air pollution, climate change, excessive water use and reduce energy consumption. Slovenes agree with it slightly more than Croats.

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ perception of air pollution sensors** | **Slovenia** | **Croatia** | **Total** |
| I expect air pollution sensors to work well | 3.9 | 3.9 | 3.9 |
| I understand the information provided by air pollution sensors | 3.2 | 3.4 | 3.3 |
| I trust the information from the sensors is accurate | 3.6 | 3.5 | 3.5 |
| I trust the information from the sensors is reliable | 3.6 | 3.5 | 3.5 |
| I would use sensors for measuring air quality, humidity and carbon monoxide in the household | 3.8 | 3.6 | 3.7 |
| I would use sensors for measuring air quality, humidity and carbon monoxide in the household even if the data was recorded | 3.6 | 3.3 | 3.5 |

Regarding air pollution sensors, all respondents on average expect air pollution sensors to work well for measuring air quality, humidity, and carbon monoxide in households, but do not understand or trust the information form sensors that well. They also do not agree strongly with collection of data from sensors. Nevertheless, they do not disagree with it. Slovenes and Croats are quite similar in their perception of this.

**Influence of environmental issues on individual behaviour**

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ beliefs about air pollution sensors use in their neighbourhoods** | **Slovenia** | **Croatia** | **Total** |
| I believe having a personal air pollution sensor will improve my neighbourhood | 3.4 | 3.4 | 3.4 |
| I believe everyone in my neighbourhood should have a personal air pollution sensor | 3.2 | 3.3 | 3.3 |
| I believe high pollution in my neighbourhood will change my attitude towards my neighbourhood | 3.6 | 3.4 | 3.5 |
| I will be motivated to consider information from the air pollution sensors while planning my activities in my neighbourhood | 3.6 | 3.4 | 3.5 |
| I believe that I would report my neighbours if they were polluting | 2.7 | 3.2 | 2.9 |

Regarding the influence of environmental issues on individual behaviour, all respondents are on average not very keen on the air pollution sensors use in their neighbourhoods. They agree slightly that everyone in the neighbourhood would have a personal sensor to improve their neighbourhood. They agree slightly that the level of pollution would affect their attitude towards their neighbourhood and their planned activities in it. They are neutral regarding reporting their neighbours if they were polluting. Slovenes and Croats are quite similar in their attitudes towards this issue.

**Privacy issues within air pollution sensors and energy consumption sensors**

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards privacy issues with service providers** | **Slovenia** | **Croatia** | **Total** |
| I am familiar with the terms and conditions in my agreement with the service providers | 2.9 | 3.1 | 3.0 |
| I am comfortable with the service providers having direct access to my data | 2.4 | 2.7 | 2.6 |
| I am willing to allow the service providers to use my data for their profit making | 2.3 | 2.5 | 2.4 |
| I trust my service providers to keep my data private | 2.9 | 2.8 | 2.9 |

Regarding privacy issues with air pollution sensor service providers, all participants are on average neutral about their familiarity with the terms and conditions in their agreement with the service providers and regarding their trust in the personal data use of the providers. However, they disagree slightly with the service providers having direct access to their data and using it for making a profit. Croats disagree with this more than Slovenes, while they are otherwise quite similar in their attitudes towards privacy issues with service providers.

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards privacy issues with air pollution sensors use** | **Slovenia** | **Croatia** | **Total** |
| Air pollution sensors are trustworthy to me | 3.4 | 3.3 | 3.3 |
| Air pollution sensors are risky to be used in terms of my privacy | 3.1 | 2.9 | 3.0 |
| My privacy would be protected when using air pollution sensors | 3.2 | 3.1 | 3.2 |
| I am concerned about my personal data when using air pollution sensors | 3.2 | 3.1 | 3.2 |
| Air pollution sensors are something that will be heavily used in the future | 3.7 | 3.5 | 3.6 |

Regarding privacy issues with the use of air pollution sensors, all participants on average agree that air pollution sensors will be heavily used in the future, but they agree only slightly that they are trustworthy or safe in terms of privacy. Slovenes and Croats are quite similar in their attitudes towards this issue.

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards data use from air pollution sensors** | **Slovenia** | **Croatia** | **Total** |
| The use of personal data for the purposes of air pollution sensors should be limited | 3.8 | 3.7 | 3.8 |
| Personal data related to the use of air pollution sensors should not be passed on to third parties | 4.1 | 3.9 | 4.0 |
| The duration of the storage of certain personal data must be limited | 4.1 | 3.8 | 4.0 |
| Misuse of personal data must be prevented | 4.6 | 4.3 | 4.4 |
| The person must be informed in advance of the potential use of personal data | 4.5 | 4.2 | 4.4 |

Regarding the use of data from air pollution sensors, all respondents on average agree strongly that they must be informed in advance of the potential use of their personal data from air pollution sensors, as well as that the misuse of it must be prevented. They also agree that the data should not be passed to third parties and should be deleted after a certain period. Moreover, they agree that the use of personal data for air pollution sensors should be limited. Slovenes and Croats are quite similar in their attitudes towards this issue.

WASTE POLLUTION

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards waste pollution management** | **Slovenia** | **Croatia** | **Total** |
| If the volume of waste production of my household became public, I would try to decrease it | 3.5 | 3.4 | 3.4 |
| If the volume of waste production of my neighbours was lower than mine, I would decrease the volume of waste production of my household | 3.2 | 3.3 | 3.2 |
| If households with greater productions of waste were fined, I would decrease waste production of my household | 3.9 | 3.6 | 3.7 |
| I would be bothered by sensors that recognize what kind of waste has been thrown inside the bin and alarm if the dropped waste does not belong to that bin | 2.7 | 2.9 | 2.8 |
| I would be willing to deposit my waste to containers that are supported by sensors that can link waste bags with me | 3.1 | 3.4 | 3.2 |
| I would be willing to deposit my waste to containers that are supported by sensors if the waste could not be linked to me | 3.6 | 3.2 | 3.4 |
| I would use sensors in my household to monitor waste production to optimize trash collection routes | 3.5 | 3.4 | 3.5 |

Regarding waste pollution, all respondents on average agree with most of the waste reduction sanctions. They would decrease their waste production more, if they were fined for it, then if their waste production would become public and they produced more of it than their neighbours. They would agree to deposit their waste in smart containers more if the waste bags were not linked to them. They would consider using sensors in their households to monitor and optimize waste collection. In general, they are not against smart waste management, except for the use of waste bins that would start an alarm when the dropped waste would not belong in them. Slovenes and Croats are quite similar in their attitudes towards this.

NOISE POLLUTION

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards noise pollution management** | **Slovenia** | **Croatia** | **Total** |
| I would agree that my city installs noise monitoring sensors in public streets | 3.3 | 3.5 | 3.4 |
| I would agree that the data provided would be sent and analysed to better improve living in my city | 3.5 | 3.5 | 3.5 |
| I would agree that noise monitoring sensors would also detect emergency critical sounds, e.g., car crashes, breaking of glass | 3.9 | 3.7 | 3.8 |

Regarding noise pollution, all participants on average agree with the use of noise monitoring sensors for the purpose of detecting emergency critical sounds, like car crashed or breaking of glass. They agree less with the use of them on public streets and further use of the collected data. Slovenes and Croats are quite similar in their attitudes towards this.

LIGHT POLLUTION

|  |  |  |  |
| --- | --- | --- | --- |
| **Individuals’ attitude towards light pollution management** | **Slovenia** | **Croatia** | **Total** |
| Light pollution is problematic | 3.8 | 3.5 | 3.7 |
| I agree with street lighting tracking my location to reduce light pollution | 3.6 | 3.3 | 3.4 |
| I would oppose different coloured street lighting | 3.0 | 3.1 | 3.1 |
| I agree with the weaker street lightning that emit less light | 3.7 | 3.5 | 3.6 |

Regarding light pollution, all participants on average agree that light pollution is problematic and would agree with a weaker street lighting and tracking of their location for light pollution reduction. They are neutral regarding the colour of streetlights. Slovenes agree with it a bit more than Croats, but they are quite similar in their attitudes towards this.

CONCLUSION

To summarise, Slovenes and Croats are very keen on the development of smart cities and believe that the new technologies can improve their personal and work life. Nevertheless, they are more interested in using smart technologies to perform very complex tasks at work, then to make important decisions for their life. Their main point of concern are security and privacy issues regarding the data collected by technologies. However, they see a great potential of smart cities for solving environmental issues and are willing to change their behaviour towards a more sustainable. Slovenes and Croats are quite similar in their perceptions and attitudes towards digitalization, sustainability, and smart cities.

# REFERENCES

1. Alves, B. (2022). Global smart grid investments 2014-2019: Statista.
2. Apostol, D., Balaceanu, C., Constantinescu, E. M. (2015). *Smart Economy Concept—Facts and Perspectives*. Paper presented at the International conference “European perspective of labor market-inovation, expertness, performance.
3. Calzada, I., Cobo, C. (2015). Unplugging: Deconstructing the smart city. *Journal of Urban Technology*, 22(1), pp. 23-43.
4. Capdevila, I., Zarlenga, M. I. (2015). Smart city or smart citizens? The Barcelona case. *Journal of Strategy and Management*.
5. European Commission. (2021). Transport and the Green Deal. Available at: <https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/transport-and-green-deal_en>.
6. Giffinger, R., Fertner, C., Kramar, H., Meijers, E. (2007). City-ranking of European medium-sized cities. *Cent. Reg. Sci. Vienna UT*, 9, pp. 1-12.
7. Haque, A. B., Bhushan, B., Dhiman, G. (2021). Conceptualizing smart city applications: Requirements, architecture, security issues, and emerging trends. *Expert Systems*.
8. Hashem, I. A. T., Chang, V., Anuar, N. B., Adewole, K., Yaqoob, I., Gani, A., . . . Chiroma, H. (2016). The role of big data in smart city. *International Journal of information management*, 36(5), pp. 748-758.
9. Israilidis, J., Odusanya, K., Mazhar, M. U. (2021). Exploring knowledge management perspectives in smart city research: A review and future research agenda. *International Journal of Information Management*, 56, 101989.
10. Kaginalkar, A., Kumar, S., Gargava, P., Niyogi, D. (2021). Review of urban computing in air quality management as smart city service: An integrated IoT, AI, and cloud technology perspective. *Urban Climate*, 39, 100972.
11. Khan, A., Aslam, S., Aurangzeb, K., Alhussein, M., Javaid, N. (2022). Multiscale modeling in smart cities: A survey on applications, current trends, and challenges. *Sustainable Cities and Society*, 78, 103517.
12. Lacinák, M., Ristvej, J. (2017). Smart city, safety and security. *Procedia engineering*, 192, pp. 522-527.
13. Lindskog, H. (2004). S*mart communities initiatives*. Paper presented at the Proceedings of the 3rd ISOneWorld Conference.
14. Manfreda, A., Ljubi, K., Groznik, A. (2021). Autonomous vehicles in the smart city era: An empirical study of adoption factors important for millennials. *International Journal of Information Management*, 58, 102050.
15. Ruohomaa, H., Salminen, V., Kunttu, I. (2019). Towards a smart city concept in small cities.
16. Shukla, S., Hait, S. (2022). Smart waste management practices in smart cities: Current trends and future perspectives. *Advanced Organic Waste Management*, pp. 407-424.
17. Vanolo, A. (2014). Smartmentality: The smart city as disciplinary strategy. *Urban studies*, 51(5), pp. 883-898.
18. Woetzel, J., Remes, J., Boland, B., Lv, K., Sinha, S., Strube, G., . . . von der Tann, V. (2018). Smart cities: Digital solutions for a more livable future: McKinsey.

**Challenges of managing a smart city: analysis of business students’ perceptions**

Introduction

Over time the cities are becoming increasingly populated and about 2/3 of global population is expected to live in urban areas by 2050 (United Nations Population Fund in Hickman, Pierson & Comstock, 2021). From the inhabitants’ perspective, the penetration of new technologies (i.e. cloud-based technology, Internet of Things/sensors/wearables, mobile apps, biometrics/facial recognition, chatbots/natural language processing, [virtual and augmented reality](https://www.simplilearn.com/top-technology-trends-and-jobs-article#5_virtual_reality_and_augmented_reality), [artificial intelligence and machine learning](https://www.simplilearn.com/top-technology-trends-and-jobs-article#1_artificial_intelligence_ai_and_machine_learning), smart beacons/near field communication, drones and robots, blockchain, etc…) in societies is the trigger for their higher adoption of the novel services provided by these technologies. However, implementation of new technologies also brings with it challenges that for older generations more difficult are to adjust (Garbin Praničević et al, 2017), whereas the younger generation grows up with contemporary technology (Peterlin & Valentinčič, 2021). Such technology is moreover seriously considered as main driving force that establishes and maintains a smart city to deliver the promised and most accepted services (Smart City Use Cases & Technology Adoption Report 2020, 2021) like connected public transport, traffic monitoring and management, water level/flood monitoring, video surveillance and analytics, connected streetlights, weather monitoring, air quality/pollution monitoring, smart metering-water, fire/smoke detection and water quality monitoring.

In general, smart cities, are cities that develop and grow at the same time. Over time different profiles of professionals thought about and now already know how to effectively use the data and digital technologies to plan and manage its core functions to become and remain efficient, innovative, inclusive and resilient. Smart cities contain an indefinite number of different technologies that affect the quality of provided city services and consequently improve the quality of the citizens lives (Kirimtat et al., 2020). The integration of digital technologies, especially artificial intelligence, into urban systems and services presents new opportunities for bringing the city closer to its citizens (World Economic Forum, 2020). Although there is still not a unified standard to measure which technology, in what size, represents a “smart city”, the smart cities are in general considered as digitalized cities that follow the goals of sustainability standards set by local, national and international standards to improve public services and achieving sustainable development (Slišković & Vrhovec, 2019). In such context, digital technologies manage extensive information to produce smart solutions such as smart city platform, to track and measure real-time demand for public transport organization based on real-time demand or to reduce the cost of urban information management (Zhang, 2019).

Moreover, a smart city systematically applies digital technologies to improve the quality of life in the city, reduces resource consumption, and increases the competitiveness of the regional economy in a long-term sustainable way. Therefore, smart city uses intelligent solutions for energy, housing, infrastructure, mobility, services and security, solutions based on integrated sensor technology, linking data analysis and other related value-added processes. From the operational aspect, smart cities have provided many projects to implement smart solutions for: waste management, reducing traffic congestion, increasing citizen safety, affordable housing, water management, smart building management, energy efficiency, renewable energy use, citizen participation in city development, and various consultations. As expected, the projects that turn a city into a smart city are mostly complex and require new competencies of all stakeholders, such as understanding the impact of the application of digital technologies within urban development and the ability to develop integrated solutions that transcend existing boundaries (Gassmann et al., 2019).

Moreover, such projects, upon implementation transform in core components of smart cities like (Habibzadeh et al., 2019):

* *Smart Environments* based on applications that provide a physical setup equipped with a large number of dedicated and non-dedicated sensors, screens, drivers and processor-powered components that are smartly integrated with everyday objects and connected via a network platform. The main factors for achieving a smart environment are adaptability, autonomy and effective communication with users;
* *Smart Homes and Buildings* focused on creating a comfortable home environment by controlling certain elements such as energy management through a system that aims to reduce electricity bills by turning off certain appliances at peak times;
* *Smart Surveillance* focuses on the gradual but continuous reduction of sensor power consumption driven by the development of sensor technologies that has enabled the use of various surveillance services;
* *Smart Transportation and Driving* includes vehicles equipped with sensory, communication, computing and process capabilities to improve safety, quality of service and efficiency;
* *Smart Health* seeks to provide health services that will improve the quality of life with the help of applications that use various sensors and actuators, as well as connecting sensory data with the analyst;
* *Smart Lighting* focuses on LED-based light sources adjust and harmonize spectral power and spatial distribution, time modulation and polarization, and color temperature. Adaptive light intensity control and the use of flashing traffic signs to warn drivers of danger are examples of popular smart lighting technology;
* *Smart Parking* seeks to reduce the negative impact on the environment and finances by using a smart parking system based on the installation of road sensors or the installation of light sensors and cameras known as field sensors;
* *Smart Grid* is an electrical grid infrastructure that uses data to create real-time models that participate in maintaining optimal grid status. The data may include information on energy produced and consumed, performance characteristics of distribution lines or availability of energy sources.

On the other side, Giourka et al. (2019) stressed out that the introduction of new technologies will not be effective if citizens do not adopt them and get involved in further activities. Evidently, smart cities concepts are slowly, but surely become in the focus of various research interests mainly due to added values manifested in (i) better use of public resources, (ii) improved the quality of services offered to the citizens (Bondarenko, Oleynik, Biryukov, Tarando, & Malinina, 2020) and (iii) reduction of the public administration operational cost (Medina, Pérez, & Trujillo, 2017). The smart solution manufacturers on the one side and decision-making authorities on the other side are both responsible stakeholders for ensuring the security of a deployed system, especially for the reason that security is recognized as the weakest link in the implementation of a smart city (Ijaz, Shah, Khan, & Mansoor Ahmed, 2016).

Accordingly, it seems as reasonable to call the educators to upgrade the study programs with competencies that will enable young people (pupils, students, online course attendees…) to be more, primarily, informed, and then included as users and/or creators of smart cities services as part of their professional engagements.

Sinergy of education institutions output and smart cities development

Following the above, we argue that role of university in knowledge management of smart city project is multiple. Moreover, in line with Ardito et al. (2019) the universities should act as knowledge intermediaries, knowledge gatekeepers, knowledge providers, and knowledge evaluators. On the same trace, Ferraris et al. (2020, p. 168) have classified the university's role in the development of the smart city ecosystem: a) “source of academic and practical knowledge (knowledge bank) – ready to enable provision and development of training programs that meet the standards of education of the “smart” city; interactive learning, accessibility of scientific literature in the mode of remote access; b) Supplier of qualified personnel – ready to enable training of specialists able to carry out innovative, managerial activities in the field of solving problems of an “intelligent” city; c) Developer – ready to providing opportunities for scientific and innovative activities, developing new business ideas, projects, technologies, for example, in the field of “Internet of Things”; d) Educational environment – ready to promote the culture of the “creative class”, the formation of new cultural values; e) Financial Mediation – ready to enable financing of the projects through helping in the presentation of smart city research proposals to national or supranational funds”

Caldwell, Foth, and Guaralda (2013, p. 7) redefine spaces of learning to places of learning through the direct engagement of local communities as a way to examine and learn from real world issues in the city. The key goal is to promote the generation and exchange of urban design ideas for the future development, informing the creation of new design policies responding to the needs of local citizens. The implementation of urban informatics techniques and approaches promoted innovative engagement strategies. Urban informatics provides an innovative opportunity to enrich students’ place of learning within the city.

Upon literature review, we claim that ongoing study programme upgrades should certainly provide students with relevant learning outputs i.e competencies to cope with certain up to date evident smart cities weakness, as follows: (i) the lack of uniform standards is necessary for the interoperability of city elements (Bašić et al., 2019), (ii) the lack of a regulatory framework for the wider adoption of smart city services in practice (Weber & Podnar, 2019), (iii) the conflicts when economic interests become more represented than environmental and social interests (Trencher, 2019), (iv) threat to privacy, censorship, surveillance and manipulation due to incomplete control and ownership of the user's account (Heitlinger et al., 2019) and (v) ethical issues concerning data privacy, data surveillance and location monitoring, cameras in public spaces (Kitchen et al., 2019).

Method

We distributed an online survey to business students at the University of Ljubljana and University of Split. 142 students answered our questions, which focused on what is their perception towards smart cities. 43% of respondents were from University of Split and 57% from the University of Ljubljana. The sample is composed of students aged 18-26 (18 years old students representing 7,1%; 19 years old students representing 26,2%; 20 years old students representing 17%; 21 years old students representing 12,1%; 22 years old students representing 10,6%; 23-years old students representing 7,8%, 24 years old students representing 10,6%; 25 years old students representing 6,4% and 26 years old students representing 2,1%). Out of 142 students, 60,6% were female and 37,3 male, while the rest preferred not to say.

We adjusted survey questions (SQs) based on several survey questionnaires, such as: 1) questions “Which mode of transport is most useful for you?«; »Which technology have you already used (more answers are possible)?«; were taken from survey Smart cities – UK city officials survey (CBRE Research, 2018); 2) question “What do you see as the top-three forms of mobility in your city in the next five years?)«; »Would you be willing to trade reduced privacy for better services?«; »How comfortable are you personally with sharing/allowing access to your personal data for the purposes of developing smart city technology?« and »What do you think are the biggest obstacles to smart city implementation?« were taken from a survey from Hickman, Pierson and Comstock (2021); 3) question »Which smart city applications are you familiar with?« (Lawhead, 2017); 4) question »If you would be a businessman/woman what would be the top three technologies you would invest in the next two years?« (Team TTR, 2018); and 5) questions »Do you expect the following technology suppliers will enable the digital transformation that will help create smart cities? (1-very low trust in their ability; 5-very high trust in their ability); and »Which technologies will take off in smart cities of the future??« (Pradeep, 2017).

Findings

Bellow we present the key findings of our study. In our first question we were interested to know which mode of transport is most useful for our students and the results show (Figure 1) that students mostly use personal vehicle (67,7%). This can be understood in the light of the need to promote and develop public transport in smart cities more and make it accessible and desirable for young people. One need is saving money and the other reason is saving the planet due to pollution.

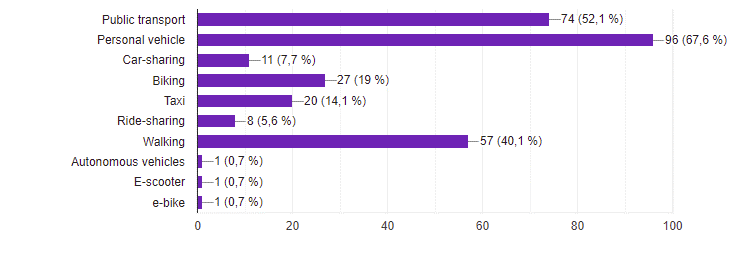


Figure 1. SQ *“Which mode of transport is most useful for you?“* (Author research, n=142)

As top-three forms of mobility in their cities in the next five years students expect to see growing role of public transportation, personal vehicle and biking (Figure 2). Several initiatives have already been implemented in terms of implementing renting bikes, micro mobility stations and car-sharing schemes in some of the Slovenian as well as Croatian cities.

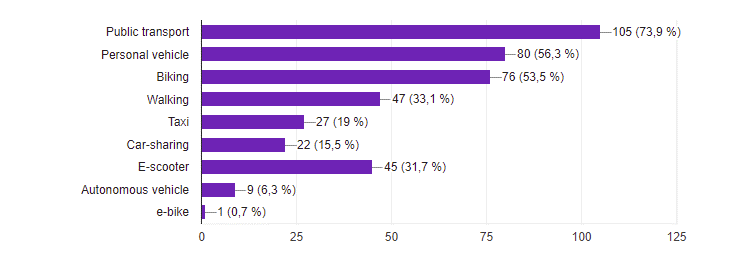
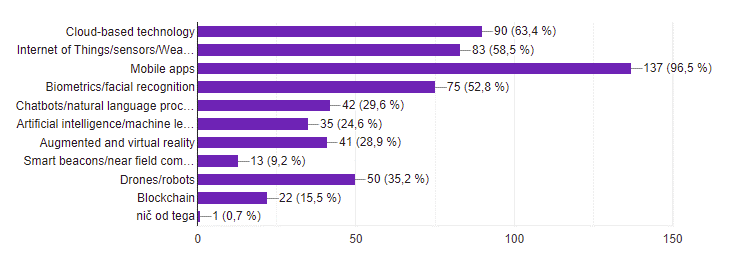
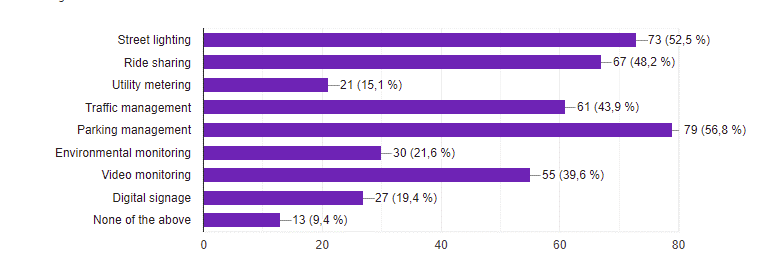
 Figure 2. SQ *“What do you see as the top-three forms of mobility in your city in the next five years?“* (Author research, n=142)

Figure 3 shows which technology business students already used. Mostly they used mobile apps, cloud-based technology and Internet of Things/sensors. Since we were conducting our survey at the business schools, it can be acknowledged that several students already develop their own mobile apps as start ups.

 Figure 3. SQ *“Which technology have you already used?”* (Author research, n=142)

From the assortment of smart city applications students are most familiar (Figure 4) with parking management, street lighting, and ride sharing. University of Ljubljana School of economics and business opened its own sustainable parking lot in 2021, called Park EF, where students can open their accounts and park their cars with a discount in a way that the system recognizes their car plates and takes automatically the money from their accounts for the duration of their parking.

 Figure 4. SQ *“Which smart city applications are you familiar with?”* (Author research, n=142)

Smart city represents different things to students and they describe it with the following definitions (key implicit theories of smart city): 1) smart city as a futuristic city with positive anticipation; 2) smart city as a threat, means of domination and control, 3) smart city as a combination of technological solutions that improve our lives; 4) smart city as a way of enabling eco and clean way of living.

Students mostly connect smart city with modern technology, robots and futuristic appliances. Even if they do not know any smart city specifically, they mostly still connect it with something from the future, something that we will need to think about more in the future and also equip ourselves with the knowledge to be able to function well in that kind of city. **Smart city as a combination of technological solutions that improve our lives category** is the most common among business students, such as the following proof citations state:

|  |
| --- |
| *Automated and efficient available public services; The city has technology to make living in the city easier; A city where you don’t waste your time; When technology eases living in the city; A city which has highly implemented the technology in its daily live; A city that is well organized with the help of technology; Automations, hassle-free processes; Easier to find a route; A city in which it is very easy to go around and function; It is a city in which technology helps with the everyday inconveniences like automatically opening rubbish bins; Created to make people lazier than we already are; That the city has useful electronic/digital assistance for the people; Temporary solutions applied to the existing issues; Set of public service solutions that help optimize daily processes in the city. For example systems that help optimize traffic congestion on certain intersection; Integration of IT and various aspects of city life (transport, parking, facilities such as hospitals, post office, etc.); optimize city functions and promote economic growth; Smart city a place where everything runs smoothly in case of traffic and internet; Smart city is very modern and technologically upgraded area, with its prime aim to upgrade everyday life; City relying on IT infrastructure to optimize transport of people, goods, energy and information throughout itself; A city where you can get all the needed information and services online; Everything will be on the apps (ticket for a bus, bike sharing...); Digitalization; easy to live in; More safety; Clean; City that uses technology in all aspects of its infrastructure (streets, roads, parking); I would describe smart city as a city where there is a lot of technology, which is used to help people of all generations, not just younger people but technology friendly to elderly people. And in a smart city its important that the people know how to use the technology that they have at hand; You can use most of the city's services with apps on your phone and pay for them with credit cards (or over mobile); City where everything goes smoothly, everything is electronic and full of smart devices such as different computers, robots…* |

Always, when we talk about novel things, our fear is how they will affect our lives. The fear is that new technology will become more powerful than humans or that we will lose control over main aspects of our lives. **Smart city as a threat, means of domination and control** is also one aspect of students’ perception of smart city:

* *things can be monitored with a phone*
* *Full of cameras and prohibited access to fundamental utilities, access available to people with smartphones*
* *Smart city is controlled and managed by technology in order to improve the quality of life.*
* *Digital Prison*
* *It means that technology will replace many human activities.*

Surprisingly, when overcoming the fear of domination that technology can have over humans, students also grasp the positive aspects of smart cities that can help us live more sustainably and environmentally friendly. Students also see the potential of **smart city to help us manage and sustain cities in a more ecological and clean way**:

* *Sustainable, led by an AI, with an emphasis on recent technological advances, decentralized*
* *eco and efficient*
* *eco and clean*
* *Emphasis on ecological aspect and technology*
* *A city that combines both - healthy environment and good communication*
* *A smart city means that people in their way of transport would personally choose to use other and environmentally friendly ways of transport over theirs. Everything around us that is not yet included would be now available on your personal devices fast and efficiently so to make the commute and everyday life easier.*
* *Cheap, efficient, environmentally friendly*
* *A city with little traffic (Artificial learning of managing traffic), low emissions, quick access to services (banks, emergency services, shops), few people working jobs that robots could do (shops without cashiers) ...*
* *Technologically advanced, better for environment, ...*
* *More citizen and environmentally friendly. You can access more things with your smart device. More automatized.*
* *Smart city investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action.*
* *A smart city enables its residents or other people to use modern technology for easier use of its services (by making data publicly available through wifi, using phones for certain reservations, minimizing paperwork, faster access to services …)*

To some students the whole concept of a smart city sounds **futuristic with positive connotation**:

* *a futuristic city*
* *A smart city is a city, that is very modern and has a lot of hi-tech technology and devices, is very automatized. I think it would be very interesting to experience this kind of world to see how life would look like.*
* *A smart city uses information and communication technology to improve operational efficiency and share information with the public. I think it is good idea because smart city is more attractive place for residents to live and promote a connected citizen experience.*

Furthermore, 61,3% of students would like to live in a smart city, while 10,65% does not wish to live in it (Figure 5).

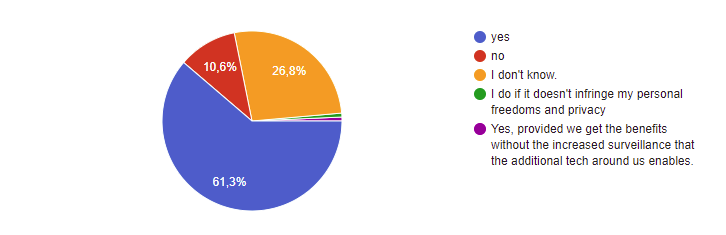


Figure 5. SQ *“Do you wish to live in a smart city?”* (Author research, n=142)

Students see the major investment possibilities in mobile and network technology, as well as big data analytics and sensor technology (Figure 6).

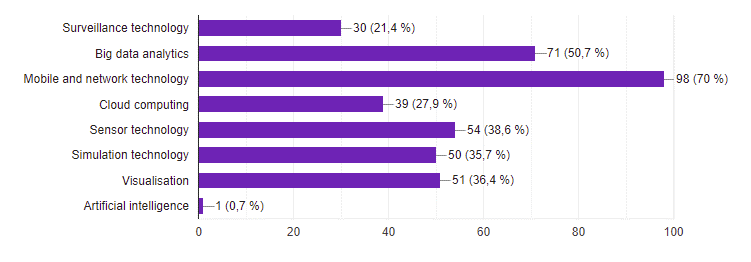


Figure 6. SQ *”If you would be a businessman/woman what would be the top three technologies you would invest in the next two years?”* (Author research, n=142)

24 students acknowledged that they do not know any smart city. Among most recognized smart cities 10 students named Tokyo due to its well organized public transportation: *What fascinates me is the amount of solutions they provide for certain ongoing problems, but at the same time it scares me a little bit, because I feel the price for that is decreased well-being and interpersonal connection, due to the amount of work that is demanded and the stimulation that the technology provides. It is really up to the individual to smartly use and not abuse these things in my opinion and I feel for that some education about the subject is needed.*

*I think Tokyo is a good example of a smart city, or any bigger cities in Japan or Korea. It’s just because the cities are in another country and I'm fascinated by their culture. They have so many new and improved things with public transportation that cannot be found anywhere else around the world.*

9 students recognized Singapore as most well-known smart city as *it has adapted the technology in order to make life easier, due to its look and modern technology that enables that the population there is well organized.* 5 students perceive Dubai as a smart city due to it does strive for sustainability and *it has the technology which is used for traffic routing, parking, infrastructure planning and transportation. They also use telemedicine and smart healthcare.*

Among cities that students perceive as smart cities are also London, New York, Bilbao, Ljubljana, Split, Rotterdam, Shanghai, Beijing, Los Angeles, Oslo, Seoul, Amsterdam, Vrgorac, Moscow, Paris, Graz, Zagreb, Munich, Madrid, Vienna, Pardubice, Barcelona, Kranj, Maribor.

Interesting example is provided from a student who is fascinated by the partnership ecosystem within the smart city of Pardubice: *Pardubice (Czech Republic) - uses new technologies that improve the functioning of the urban ecosystem. Thanks to new technologies, the operation of the city is simpler, more environmentally friendly and energy-efficient. What fascinates me is that it is not that big city and still it is able and trying to do the best for being a smart city. Another thing is involvement of students and local people, for example the local University of Pardubice, specifically the Faculty of Electrical Engineering and Informatics, also took part in the cooperation on the Pardubice project.*

Students perceive that 5G, artificial intelligence, machine learning and mobile phone apps will take off in smart cities in the Figure 7.

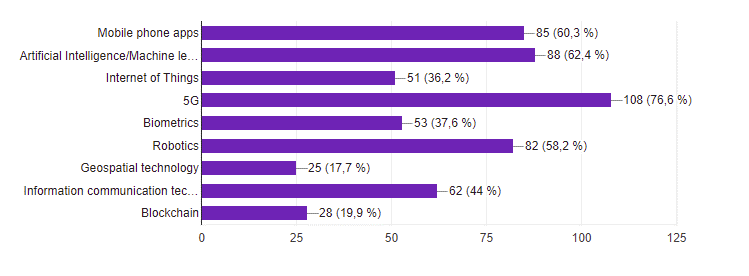


Figure 7. SQ *“Which technologies will take off smart cities of the future?”* (Author research, n=142)

52,2% of students is not willing to trade privacy for better service (Figure 8). When we asked additional question “How comfortable are you personally with sharing/allowing access to your personal data for the purposes of developing smart city technology?” 59,9% of students said no (Figure 9).

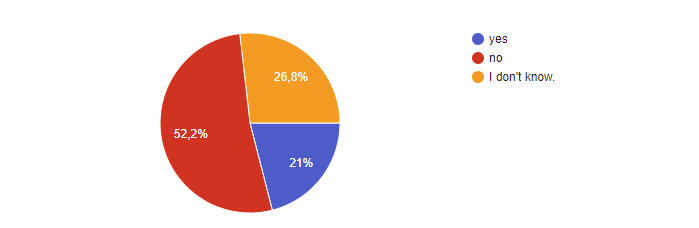


Figure 8. SQ *”Would you be willing to trade reduced privacy for better services?”* (Author research, n=142)

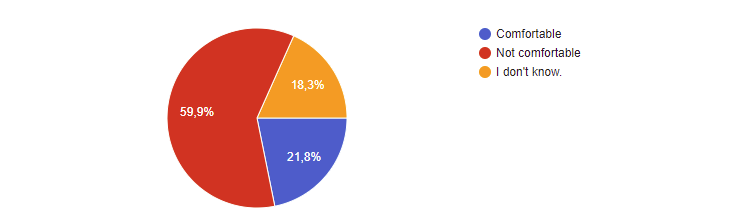


Figure 9. SQ *“How comfortable are you personally with sharing/allowing access to your personal data for the purposes of developing smart city technology?”* (Author research, n=142)

Students perceive financing, national security concerns and the sharing of data to enable new technology (Figure 10).

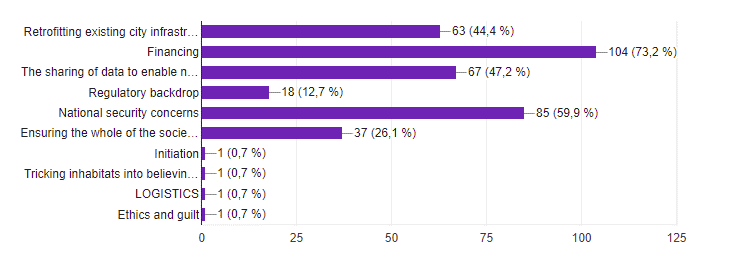


Figure 10. SQ *“What do you think are the biggest obstacles to smart city implementation?”* (Author research, n=142)

Discussion and conclusion

Challenges that smart cities are dealing with are growing, and over time stand as imperative for current business students. Respectively, high educated business staff needs to be prepared as much as possible, to face them and consider the topic from a broader perspective. In that context, some related reflections and considerations derive from this research results.

Having in mind that climate change is the key challenge being addressed in our time (European Environment Agency, 2021) the use of personal vehicle (Figure 1) as the most useful mode of transport is not the most optimal solution. However, comparing the same questions with CBRE Research (2018) provided by officials in 14 UK cities, the CBRE findings are only slightly more favorable and indicate that personal vehicles are the second most used means of transportation, just behind public transport. Yet, the delightful fact is that, the transport mode, which, the students suppose, their cities residents will gravitate towards in the short term is dominantly public transport, with significantly growth of biking and e-scooter use (Figure 2).

The more the technology is used, like mobile apps, cloud-based technology and Internet of Things / sensors (as presented in Figure 3), the better is understood, even accepted, smart service platforms through which such digital technology has been increasingly embedded in social creativity as elaborated in the study (Anttiroiko et al., 2014). On the same line, the more as familiarity with the assortment of smart city applications grows, like with parking management, street lighting, ride sharing (as presented in Figure 4) more positive social change driven by ICT adoption may be expected, but also wider understanding of the smart cities and its specifies (Kummitha & Crutzen, 2017).

Given that just over 60 % (Figure 5) of respondents expressed a desire to live in a smart city, the more responsible both, in smart cities management and in process of training and education, need to pay additional attention to cope with smart cities weakness (Bašić et al., 2019; Heitlinger et al., 2019; Kitchen et al., 2019; Trencher, 2019; Weber & Podnar, 2019), as already mentioned previously in this research. However, the core question remains whether fixing the downsides would significantly affect the tendency to maintain privacy, which is according to our findings high (concisely by Figures 8 and 9). Threat to privacy, censorship, surveillance and manipulation due to incomplete control and ownership of the user's account are not enough explored areas and thus opportunity for a new research. To this should be added a call for further research into the possible links between data sharing and threats to national security, as suggested by the results of this study (Figure 10).

Taking into account the raising trend toward digital governance of data driven smart cities (Dubman, 2019), the major investment possibilities in mobile and network technology, big data analytics and sensor technology (as presented in Figure 6) seems very certain and understandable, then consequently, the number of investors from all over (CB Insights, 2021) is expected to raise.

Finally, respecting that 5G, artificial intelligence, machine learning and mobile phone apps will take off in smart cities (as presented in Figure 7), and, in line with many recent studies outputs (Allam & Dhunny, 2019; Almao & Golpayegani, 2019; Guevara & Auat Cheein, 2020; Nosratbadi et al., 2019; Voda & Radu, 2018), we repeat and point out again the important role of university in training/educating future staff to be “solving problems” with technologies, not using technologies for the sake of using it.

Contribute to this is the perception of the university as a mediator of knowledge (Ardito et al., 2019) with offer a wide range of roles and occupations required for the development of smart city ecosystem (Ferraris et al., 2020).

Smart city can be presented to students through the following learning modality mechanisms within corporate as well as educational institutions: a) virtual classroom learning on the smart city functioning and technology needed to function (facilitator-led with two way interaction but no need for co-location); b) instructor-led (facilitator-led to allow for in-person interaction); c) academic courses on specific aspects of smart cities (internal or external series of structured courses/content, possibly for academic credit); d) program in collaboration with the mayor of a chosen smart city (structured learning focused on a topic, capability, role, etc.); e) discussion boards on topics concerning smart city technology which produces fear or excitement (online site with groups for learning, discussions and questions); f) collaboration tools (learners can identify peer "experts", search peer-generated content, and share their own resources); g) peer feedback on own experiences with the technology and benefits that smart cities offer (peers review and provide feedback to other peers to learn from each other); h) coaching/mentoring from smart city experts from different disciplines (on-on-one interactions to provide support and reinforcement); i) web based (e-learning to reach large numbers of dispersed learners); j) job aids on new professions that smart city needs (self-study materials to provide information when needed by the learner, such as Quick reference guides); k) podcasts and videos of smart city cases (internal or external content focused on market trends, management skills, an more); l) interactive support (internal support team to answer day-to-day questions via phone or online chat); m) QR codes/beacons (Geo-based activities connecting learning to a specific location); n) voice recognition (hands free technology providing access to information without stopping work); and o) mobile learning (mobile access to the learning platform) (Deloitte, COVID-19 - The upskilling imperative, 2022).

Teaching staff could collaborate more closely with identified good practice role models of smart cities, such as Ēvora, Torino, Leuven, Amsterdam, Johannesburg, Trikola, Hangzhou, Changsha, Dehradun, Nagpur, Allahabad, Pune, Nara, Singapure, Newark, Quayside, Porto Alegre, Algiers (Anthopoulos, 2019). The city of Vienna (Roblek, 2019) was also identified as a smart city in the nearby vicinity of Slovenia and Croatia, therefore excursions could be held to show students the characteristics of functioning smart city, nowadays and the challenges they are facing and students could help in solving.

We wish to conclude with a quote from one of the participants: *I didn’t know that smart cities exist already and was fascinated that smart cities exist already nowadays and that they even exist in my country.* We think that students need to be introduced to the concept of smart city in a business classroom as it will affect their everyday lives as well as enable them professional opportunities in the near future.

**REFERENCES**

1. Allam, Z., Dhunny, Z. A. (2019). On big data, artificial intelligence and smart cities. *Cities*, 89, pp. 80-91.
2. Almao, E. C., Golpayegani, F. (2019). Are mobile apps usable and accessible for senior citizens in smart cities?, In: *International Conference on Human-Computer Interaction*, Springer, Cham, pp. 357-375.
3. Anthopoulos, L. (2019). *Smart City Emergence: Cases from Around the World*. Oxford: Elsevier Inc.
4. Anttiroiko, A. V., Valkama, P., Bailey, S. J. (2014). Smart cities in the new service economy: building platforms for smart services. *AI & society*, 29(3), pp. 323-334.
5. Ardito, L., Ferraris, A., Petruzzelli, A. M., Bresciani, S., Del Giudice, M. (2019). The role of universities in the knowledge management of smart city projects*. Technological Forecasting and Social Change*, 142, pp. 312-321.
6. Bašić, S., Vezilić Strmo, N., Sladoljev, M. (2019). Smart cities and buildings. *Građevinar*, 71(10.), pp. 949-964.
7. Bondarenko, N. G., Oleynik, A., Biryukov, V. A., Tarando, E. E., Malinina, T. B. (2020). Smart city: integration of information and communication technologies. *IIOAB Journal*, 11(3), pp. 106-110.
8. Caldwell, G., Foth, M., Guaralda, M. (2013). An urban informatics approach to smart city learning in architecture and urban design education. *Interaction Design and Architecture (s)*, 2013(17), pp. 7-28.
9. CB Insights (2021). Here’s Where the Top Smart Cities Investors Are Placing Their Bets. Available at: <https://www.eea.europa.eu/themes/climate/climate-change-is-one-of> (Accessed: December 28, 2021).
10. Deloitte (2022). COVID-19 - The upskilling imperative: Building a future-ready workforce for the AI age. Available at: <https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/deloitte-analytics/ca-covid19-upskilling-EN-AODA.pdf> (Accessed: January 7, 2022).
11. Dubman, R. (2019). The digital governance of data-driven smart cities: Sustainable urban development, big data management, and the cognitive Internet of Things. *Geopolitics, History, and International Relations*, 11(2), pp. 34-40.

## European Environment Agency (2021). Climate change mitigation. Available at: <https://www.eea.europa.eu/themes/climate/climate-change-is-one-of> (Accessed: December 28, 2021).

1. Ferraris, A., Belyaeva, Z., Bresciani, S. (2020). The role of universities in the Smart City innovation: Multistakeholder integration and engagement perspectives. *Journal of Business Research*, 119, pp. 163-171.
2. Garbin Praničević, D., Peterlin, J. & Bućan, M. J. (2017). Do older people benefit from digital services?. In: *DIEM: Dubrovnik International Economic Meeting*, 3(1), pp. 145-160.
3. Gassmann, O., Böhm, J., Palmié, M. (2019). *Smart cities: introducing digital innovation to cities*. Emerald Group Publishing.
4. Giourka, P., Sanders, M. W., Angelakoglou, K., Pramangioulis, D., Nikolopoulos, N., Rakopoulos, D., Tryferidis, A., Tzovaras, D. (2019). The smart city business model canvas—A smart city business modeling framework and practical tool. *Energies*, 12(24), p. 4798.
5. Guevara, L., Auat Cheein, F. (2020). The role of 5G technologies: Challenges in smart cities and intelligent transportation systems. *Sustainability*, 12(16), p. 6469.
6. Habibzadeh, H., Kaptan, C., Soyata, T., Kantarci, B., Boukerche, A. (2019). Smart city system design: A comprehensive study of the application and data planes. *ACM Computing Surveys (CSUR)*, 52(2), pp. 1-38.
7. Heitlinger, S., Bryan-Kinns, N., Comber, R. (2019). The right to the sustainable smart city. In: *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pp. 1-13.
8. Hickman, T., Pierson, A., Comstock, E. (2021). How changing attitudes toward data sharing could accelerate smart city adoption. Available at: <https://www.whitecase.com/publications/insight/how-changing-attitudes-toward-data-sharing-could-accelerate-smart-city> (Accessed: September 17, 2021).
9. Ijaz, S., Shah, M. A., Khan, A., Mansoor Ahmed, M. (2016). Smart Cities: A Survey on Security Concerns. *International Journal of Advanced Computer Science and Applications*, 7, pp. 612-625.
10. Kirimtat, A., Krejcar, O., Kertesz, A., Tasgetiren, M. F. (2020). Future trends and current state of smart city concepts: A survey. *IEEE Access*, 8, pp. 86448-86467.
11. Kitchen, R., Cardullo, P., & Di Feliciantonio, C. (2019). Citizenship, justice, and the right to the smart city. In *The right to the smart city*. Emerald Publishing Limited.
12. Kummitha, R. K. R., Crutzen, N. (2017). How do we understand smart cities? An evolutionary perspective. *Cities*, 67, pp. 43-52.
13. Lawhead, D. (2017). Which US cities can benefit most from smart city transformation?. Available at: <https://enterpriseiotinsights.com/20171005/smart-cities/us-cities-benefit-smart-city-transformation-tag17> (Accessed: September 17, 2021).
14. Medina, C. A., Pérez, M. R., Trujillo, L. C. (2017). IoT paradigm into the smart city vision: a survey. In: *2017 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, IEEE, pp. 695-704.
15. Nosratabadi, S., Mosavi, A., Keivani, R., Ardabili, S., Aram, F. (2019). State of the art survey of deep learning and machine learning models for smart cities and urban sustainability. In: *International Conference on Global Research and Education,* Springer, Cham, pp. 228-238.
16. Peterlin, J., Valentinčič, D. (2021). Analiza trajnostnega vodenja skupnosti avstralskih Slovencev: Primer S.A.S. & S. Club “Jadran” (Sustainable leadership analysis of Australian Slovenians: case of S.A.S. & S. Club “Jadran”. In: Redek, T. (eds). *Izzivi podjetij, države in družbe v uresničevanju odgovornosti za trajnostni razvoj*, Ljubljana: Ekonomska fakulteta Univerze v Ljubljani, pp. 235-253.
17. Pradeep (2017). Microsoft is the most trusted smart-city vendor according to a survey by IDC. Available at: <https://mspoweruser.com/microsoft-trusted-smart-city-vendor-according-survey-idc/> (Accessed: September 17, 2021).
18. Roblek, V. (2019). The smart city of Vienna. In: Anthopoulos, L. (eds). *Smart City Emergence*. Oxford: Elservier, pp. 105-129.
19. Slišković, T., Vrhovec, I. (2020). Realizacija projekata baziranih na konceptu „pametnih “gradova u Hrvatskoj s osvrtom na grad Jastrebarsko. *Notitia-časopis za ekonomske, poslovne i društvene teme*, 6(1), pp. 63-80.
20. Smart cities – UK city officials survey (CBRE Research, 2018; ESI ThoughtLab 2018). CBRE, United Kingdom. Available at: <https://www.cbre.co.uk/research-and-reports/our-cities/smart-cities-uk-city-officials-survey> (Accessed: September 17, 2021).
21. Smart City Use Cases & Technology Adoption Report 2020 (2021). Available at: <https://iot-analytics.com/top-10-smart-city-use-cases-prioritized-now/> (Accessed: September 17, 2021).
22. Team TTR (2018). Smart City Survey Results: Governments Need to Be Smarter About Keeping Cities Safe. Available at: <https://thetechrevolutionist.com/2018/02/smart-city-survey-results-governments.html> (Accessed: September 17, 2021).
23. Trencher, G. (2019). Towards the smart city 2.0: Empirical evidence of using smartness as a tool for tackling social challenges. *Technological Forecasting and Social Change*, 142, pp. 117-128.
24. Voda, A. I., Radu, L. D. (2018). Artificial intelligence and the future of smart cities. BRAIN. *Broad Research in Artificial Intelligence and Neuroscience*, 9(2), pp. 110-127.
25. Weber, M., Podnar Žarko, I. (2019). A regulatory view on smart city services. *Sensors*, 19(2), p. 415.
26. World Economic Forum (2020). Smart at Scale: Cities to Watch, 25 Case Studies. Available at: <http://www3.weforum.org/docs/WEF_Smart_at_Scale_Cities_to_Watch_25_Case_Studies_2020.pdf> (Accessed: November, 2021).
27. Zhang, C. (2020). Design and application of fog computing and Internet of Things service platform for smart city. *Future Generation Computer Systems*, 112, pp. 630-640.

CRITERIA EVALUATION FOR SELECTING IOT PLATFORMS IN SMART CITIES: EVIDENCE FROM CROATIA AND SLOVENIA

INTRODUCTION

The Smart City (SC) concept has recently received a lot of attention. The number of papers has expanded dramatically in the last seven years, according to a Scopus database search conducted in February 2022. This indicates that more research and practical application of the above-mentioned notion are required. A smart city, according to the European Commission, is *a place where traditional networks and services are made more efficient via the use of digital and communications technology for the benefit of its residents and businesses* (EK, 2020). Digital and telecommunication technologies cannot be used in isolation; for a city to become smart, it must have a high level of information technology integration and broad use of information resources (Kim, Ramos and Mohammed, 2017).

The new emerging concept of the Internet of Things (IoT) has become a vital agenda when considering the future of information and communication technologies (ICT) (Kim and Kim, 2016). It enables remote monitoring, managing and controlling of devices, as well as creating knowledge from real-time data (Kim, Ramos and Mohammed, 2017; Nunes *et al.*, 2017; Alelaiwi, 2019). The IoT can be viewed as an ecosystem that links physical objects (sensors) to telecommunication networks, bridging the gap between the physical and virtual worlds and enabling the creation of new services and applications (Nunes *et al.*, 2017). IoT assumes installing and connecting sensors to the internet through specific protocols for information exchange to accomplish intelligent recognition, location, tracking, monitoring, and management (Kim and Kim, 2016; Silva and Jardim-Goncalves, 2021). Successful implementation of IoT platforms could bring up significant benefits, e.g., efficiency, effectiveness, safety, security, and quality decision-making (Kim and Kim, 2016). In addition, IoT platforms are the most crucial component of the IoT concept because they bridge the gap between device sensors and data networks. The platform links data to the sensor system and provides insights via back-end apps, allowing users to obtain a sense of the enormous amount of data flowing in from various sensors (Nunes *et al.*, 2017).

A wide range of IoT integration platforms became recently available (Abdelmegid *et al.*, 2020) and therefore, the number of platforms providers (vendors) is also growing. Furthermore, research company Gartner (2020) expects the global government IoT endpoint electronics and communications market to reach $17.4 billion in 2021 (Gartner, 2020). Relevant IoT end-users in the smart city (e.g., city administrators, managers, decision-makers and policy planners) need to answer crucial questions related to the selection of the IoT platforms that are to be implemented. Different IoT technologies in smart cities enable the utilization of different devices, which would increase the life quality in cities as well as the efficiency of various daily services (Nižetić *et al.*, 2020). Selecting the most suitable platform for individual users is a critical challenge (Mashal, Alsaryrah and Chung, 2020). The literature shows the existence of few criteria and alternatives when selecting an IoT platform, where neither is dominant (Contreras-Masse *et al.*, 2019).

Given the above, the motivation of this paper lies in a practical and theoretical need to investigate *whether commonly used criteria for the selection of technology, in general, are applicable for IoT platforms* *as a part of the smart city concept.* In addition, the presented study aims to answer the derived research question of *whether differences exist in the perceived importance of IoT platforms' selection criteria between end-users and vendors in Croatia and Slovenia*. This research gap has been partially addressed by (Mijač, Ninčević Pašalić and Tomat, 2021), however, future research directions refer to expanding the number and diversity of participants as well as including some vendors and smart city managers in wider geographical regions (Slovenia). With this paper, the authors fill the research gap by including non-IT experts in evaluating the criteria and comparing previously collected data with another geographical area - Slovenia. This approach has not been presented before to the best of our knowledge.

The environment considered for this study includes the smart cities of Croatia and Slovenia. As stated previously, a city could be considered "smart" if it has a project in one or more of the six dimensions (Giffinger and Gudrun, 2010). Taking into consideration more strict approach - the SC maturity levels (EU, 2014), research conducted on the 20 largest Croatian cities (over 25.000 inhabitants) confirmed that only four cities (20%) meet this criterion and thus categorise as a smart city while two more are in the process of developing their SC strategies (Ninčević Pašalić, Jadrić and Ćukušić, 2020). As for Slovenia, authors (Pušnik *et al.*, 2019) consider Ljubljana, Maribor, Koper and Kranj as smart cities (which is approximately 20% of 20 largest Slovenian cities).

The rest of the paper consists of 5 chapters. Chapter 2 gives a theoretical background on the IoT domain, IoT platform and criteria used. Chapter 3 shortly introduces the methodology used, while chapter 4 presents the results of the evaluated criteria. Chapters 5 and 6 discuss results and conclude the paper with final remarks, listed limitations and avenues for future research.

THEORETICAL BACKGROUND

The main goal of IoT technologies is to simplify processes in different fields, ensure better efficiency of systems (technologies or specific processes), and improve life quality (Nižetić *et al.*, 2020).

Small sensors implanted in smart items such as electronic devices, alarm systems, cars, home appliances, and industrial machines make up the Internet of Things system, which allows them to communicate with one another and with their surroundings (Nunes *et al.*, 2017). Because the Internet of Things domain is even more innovative than the Smart City concept itself, the articles on criteria selection are primarily based on a review of existing literature. Technology, market, and laws, for example, have all been studied in the past (Baumgärtner and Winkler, 2003). Furthermore, as the authors point out, there has been minimal research on the interoperability of IoT platforms from a business value perspective, taking into account both technical and non-technical elements as selection criteria for adopting such platforms (Abdelghaffar and Abousteit, 2021).

Other authors have presented a multi-criteria approach using three main criteria for IoT applications (Kim and Kim, 2016): (1) technological prospect, (2) market potential and (3) regulatory environment. The recent paper points out that smart objects differ in their technical specifications due to their variations in design and features; thus, specific subcriteria can also be derived (Mashal, Alsaryrah and Chung, 2020).

Their conclusions may be constrained from a methodological standpoint because they rely on respondents who are primarily experts with ICT backgrounds. Furthermore, several authors have offered a systematic framework for evaluating IoT, although empirical research is lacking in the literature (Silva and Jardim-Goncalves, 2017). Literature review analysis confirmed that different criteria could be found depending on the type of technology (e.g., database, cloud, etc.). Even though *interoperability* as criterion is especially highlighted when considering the selection of smart objects (Mashal, Alsaryrah and Chung, 2020); however, it could be considered within the criteria of *integration flexibility* and *standardization*. The list of criteria, information about the IoT domain and authors who investigated the criteria are summed in Table 1.

Table 1: IoT selection criteria

|  |  |
| --- | --- |
| ***Criteria*** | ***Authors*** |
| Platform reliability | (Kim and Kim, 2016; Kondratenko, Kondratenko and Sidenko, 2019; Mashal, Alsaryrah and Chung, 2020) |
| Platform price | (Kim and Kim, 2016; Singla *et al.*, 2018; Lin *et al.*, 2020) |
| Standardization | (Kim and Kim, 2016) |
| Platform scalability | (Lin *et al.*, 2020) |
| Platform security | (Kondratenko, Kondratenko and Sidenko, 2019; Lin *et al.*, 2020) |
| Platform usability | (Thomas, Onyimbo and Logeswaran, 2016; Alelaiwi, 2019; Lin *et al.*, 2020; Mashal, Alsaryrah and Chung, 2020) |
| Integration Flexibility | (Kondratenko, Kondratenko and Sidenko, 2019; Lin *et al.*, 2020) |
| Platform availability | (Singla *et al.*, 2018; Lin *et al.*, 2020; Mashal, Alsaryrah and Chung, 2020) |
| Platform security | (Kim and Kim, 2016; Kondratenko, Kondratenko and Sidenko, 2018; Uslu *et al.*, 2019; Lin *et al.*, 2020) |
| Device management | (Kondratenko, Kondratenko and Sidenko, 2019) |
| Platform functionalities | (Kondratenko, Kondratenko and Sidenko, 2019; Lin *et al.*, 2020) |
| Usefulness of visualization | (Kondratenko, Kondratenko and Sidenko, 2019) |
| Variety of data analytics tools/possibilities | (Kondratenko, Kondratenko and Sidenko, 2019) |
| Platform portability | (Alelaiwi, 2019) |
| Supportability (from vendor/provider) | (Alelaiwi, 2019) |

Source: adapted from Mijač, Ninčević Pašalić and Tomat (2021)

Criteria that were deemed irrelevant (outside of the scope of an IoT platform) were omitted from the analysis, leaving the authors to concentrate solely on the general ones (e.g. market longevity). The literature review yielded the following 15 criteria: availability, security, price, reliability, device management, integration flexibility, manufacturer quality, portability, scalability, standardization, supportability, functionality, usability, visualization utility, and data analytics variety.

METHODOLOGY

In the process of decision making, decision-maker(s) evaluate the importance of criteria in terms of priorities or weights. In this study, *group weight assessment* has been conducted with experts*.* Using the grading method, vendors and end-users (in the role of experts) were presented with criteria and were asked to award a grade for each criterion in an interval from 0 to 100. The weight were calculated using the following formula (1):

(1)

(2)

where *n* signifies the number of alternatives, 𝜌𝑗𝑘 the grade from expert *k* to criteria *j*, 𝑤𝑗𝑘 signifies normalised weight calculated for criteria *j* from expert *k*, and 𝑤𝑗 (2) stands as the total weight for criteria *j*. The weights are required for multi-criteria decision-making (MCDMthat is known as decision-making with conflicting criteria and a limited number of alternatives (Babić, 2017).

The research instrument was prepared by the authors following the results of the literature review. It contained the essential criteria (N=15) for selecting an IoT platform that required expert grad. Additionally, experts were asked to add any other criterion in case they thought any was missed by the authors.

Subsequently, a descriptive comparison of Croatian and Slovenian results has been done as described in Chapter 4.

RESULTS

In total, 16 experts participated in the evaluation, half of whom were end-users (N=8) and the other half vendors (N=8). Half of the participants are from Croatia and half from Slovenia. Results of the experts' evaluation yielded additional three criteria: *customer support team*, *intuitive user interface* and *privacy/data protection*. However, all of them could be considered contained within the listed criteria (Table 1). Criteria weights were calculated for each group of experts and each country, and sorted starting from the highest rated criteria.

Croatia

Calculated and sorted weights for Croatian vendors and end-users are shown in Table 2.

Table 2: Criteria weights according to vendors and end-users in Croatia

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Criteria*** | ***Weight according to vendors*** |  | ***Criteria*** | ***Weight according to end-users*** |
| Device management (w7) | 0.079113 |  | Platform functionalities (w3) | 0.079803 |
| Platform scalability (w13) | 0.078988 |  | Platform security (w12) | 0.077991 |
| Platform security (w12) | 0.078595 |  | Platform scalability (w13) | 0.075378 |
| Platform price (w1) | 0.078115 |  | Platform portability (w10) | 0.075338 |
| Platform functionalities (w3) | 0.076955 |  | Device management (w7) | 0.073527 |
| Platform usability (w15) | 0.072585 |  | Platform usability (w15) | 0.071295 |
| Platform reliability (w9) | 0.069821 |  | Variety of data analytics tools/possibilities (w11) | 0.068741 |
| Platform portability (w10) | 0.068907 |  | Platform price (w1) | 0.066489 |
| Variety of data analytics tools/possibilities (w11) | 0.06439 |  | Platform reliability (w9 | 0.065058 |
| Usefulness of visualization (w6) | 0.05993 |  | Integration flexibility (w5) | 0.064618 |
| Integration flexibility (w5) | 0.05868 |  | Usefulness of visualization (w6) | 0.062425 |
| Platform availability (w2) | 0.055584 |  | Platform provider quality and reputation (w4) | 0.057639 |
| Standardization (w14) | 0.055387 |  | Platform availability (w2) | 0.056438 |
| Platform provider quality and reputation (w4) | 0.051923 |  | Supportability (from vendor/provider) (w8) | 0.053536 |
| Supportability (from vendor/provider) (w8) | **0.051026** |  | Standardization (w14) | **0.051725** |

As seen in Table 2, the most important criteria for end-users while selecting the IoT platform is *functionality*. It is interesting to point out that, except for criteria *price*, every other criterion has been rated as more important by IoT vendors than it has been by end-users. Unexpectedly, *price* is considered a more important criterion by vendors than end-users in Croatia. However, *security* and *scalability* are perceived as the top 20% criteria by both vendors and end-users.

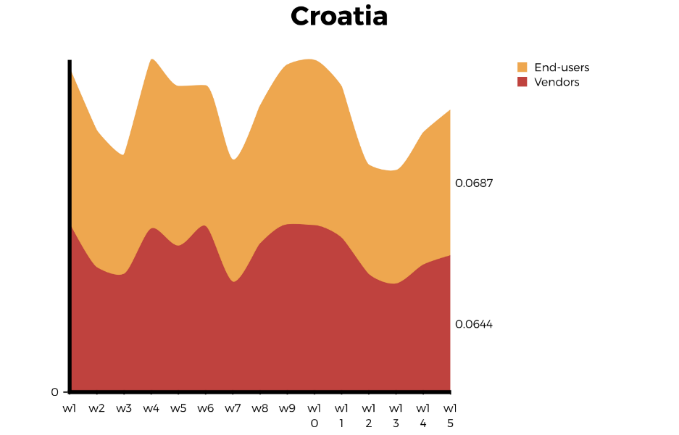
****

Figure 1. Comparison of weight between vendors and end-users in Croatia

Slovenia

Calculated and sorted weights for vendors and end-users from Slovenia are shown in Table 3. Values are sorted from the highest to the lowest. It can be seen that, when taking into consideration the top 20% criteria, only one criterion is common for end-users and vendors in Slovenia – platform functionality.

Table 3: Criteria weights according to vendors and end-users in Slovenia

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Criteria*** | ***Weight according to vendors*** |  | ***Criteria*** | ***Weight according to end-users*** |
| Platform availability (w2) | 0.090967943 |  | Platform functionalities (w3) | 0.078149 |
| Platform reliability (w9) | 0.088846289 |  | Platform security (w12) | 0.077481 |
| Platform functionalities (w3) | 0.07691157 |  | Platform scalability (w13) | 0.076901 |
| Platform usability (w15) | 0.076407563 |  | Platform usability (w15) | 0.074301 |
| Platform price (w1) | 0.07280326 |  | Integration flexibility (w5) | 0.073976 |
| Platform security (w12) | 0.072086251 |  | Platform availability (w2) | 0.072052 |
| Supportability (from vendor/provider) (w8) | 0.071640406 |  | Platform price (w1) | 0.068501 |
| Integration flexibility (w5) | 0.069923261 |  | Platform portability (w10) | 0.068402 |
| Device management (w7) | 0.063408224 |  | Device management (w7) | 0.065366 |
| Standardization (w14) | 0.061395405 |  | Variety of data analytics tools / possibilities (w11) | 0.063541 |
| Platform scalability (w13) | 0.061162562 |  | Platform reliability (w9) | 0.062185 |
| Usefulness of visualization (w6) | 0.057525871 |  | Usefulness of visualization (w6) | 0.060929 |
| Platform portability (w10) | 0.053895405 |  | Standardization (w14) | 0.05718 |
| Variety of data analytics tools / possibilities (w11) | 0.047339033 |  | Platform provider quality and reputation (w4) | 0.051097 |
| Platform provider quality and reputation (w4) | **0.035686955** |  | Supportability (from vendor/provider) (w8) | **0.049938** |

Calculated weights for each criteria are graphically presented in the figure below (Figure 2).

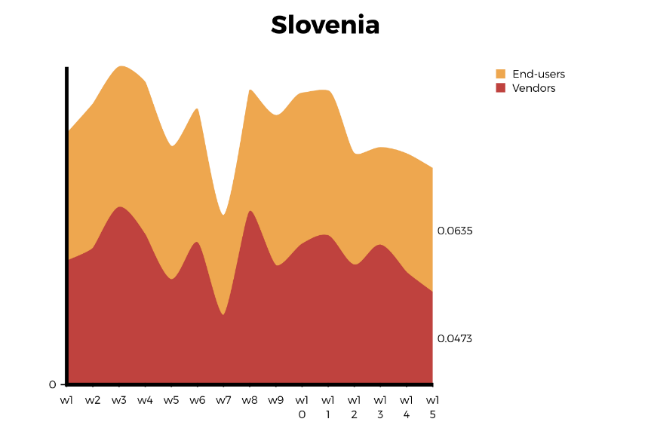
****

Figure 2. Comparison of weight between vendors and end-users in Slovenia

Comparison

Calculated criteria weights according to **vendors** in **Slovenia (SLO)** and **Croatia (CRO)** have been compared and shown in the table below (Table 4).

The top 20% of the highest weights are colored in green, while 20% of the lowest value has been marked with red cells. After observing calculated values, it can be stated that vendors agree only on one criterion – most minor graded *Platform provider quality and reputation*. According to that, it can be said that the agreement level between vendors is 1% (1/15).

Table 4: Croatian and Slovenian vendors

|  |  |  |
| --- | --- | --- |
| Criteria | **Vendors SLO** | **Vendors CRO** |
| Device management | 0.063408224 | 0.079113189 |
| Integration flexibility | 0.069923261 | 0.0586795 |
| Platform availability | 0.090967943 | 0.055584428 |
| Platform functionalities | 0.07691157 | 0.076955329 |
| Platform portability | 0.053895405 | 0.068907204 |
| Platform price | 0.07280326 | 0.078115165 |
| Platform provider quality and reputation | **0.035686955** | 0.051922745 |
| Platform reliability | 0.088846289 | 0.069820768 |
| Platform scalability | 0.061162562 | 0.078987849 |
| Platform security | 0.072086251 | 0.078594689 |
| Platform usability | 0.076407563 | 0.072585278 |
| Standardization | 0.061395405 | 0.055387329 |
| Supportability (from vendor/provider) | 0.071640406 | **0.051026439** |
| Usefulness of visualization | 0.057525871 | 0.05992999 |
| Variety of data analytics tools / possibilities | 0.047339033 | 0.064390095 |
| **Max** | 0.090967943 | 0.079113189 |
| **Min** | 0.035686955 | 0.051026439 |

Comparison results indicate that difference in perceiving the importance of criteria exists when comparing the results from IoT vendors in Croatia and Slovenia.

The most important criterion according to vendors in Slovenia is *platform availability*, while vendors in Croatia consider the most important criteria *device management*. Criteria *platform provider quality and reputation* have been graded with the lowest weight according to Slovenian vendors, while Croatian vendors graded *supportability (from vendor/provider*) as the least important.

Interestingly, weight values for Slovenia vendors range from 0.035686955 to 0.090967943, while Croatian vendors graded the criteria with a much lower range [0.051026439, 0.079113189].

When comparing the results collected from **end-users** in **Croatia** and **Slovenia**, the results show that end-users in Slovenia and Croatia share the opinion on 75% of the top 30% of calculated values. Calculated values are shown in Table 5 and marked as previously noted.

Also, weight values for Slovenia end-users range from 0.049938 to 0.078149, similar to Croatian end-users ranging from 0.051725 to 0.079803.

End-users from Slovenia and Croatia have a level of agreement of 33% (they agree on 5 out of 15 criteria). Also, they both graded the criteria *platform functionality* as the most important one.

Table 5: End-users from Croatia and Slovenia

|  |  |  |
| --- | --- | --- |
| Criteria | **End-users SLO** | **End-users CRO** |
| Device management | 0.065366 | 0.073527 |
| Integration flexibility | 0.073976 | 0.064618 |
| Platform availability | 0.072052 | 0.056438 |
| Platform functionalities | **0.078149\*** | **0.079803\*** |
| Platform portability | 0.068402 | 0.075338 |
| Platform price | 0.068501 | 0.066489 |
| Platform provider quality and reputation | 0.051097 | 0.057639 |
| Platform reliability | 0.062185 | 0.065058 |
| Platform scalability | 0.076901 | 0.075378 |
| Platform security | 0.077481 | 0.077991 |
| Platform usability | 0.074301 | 0.071295 |
| Standardization | 0.05718 | **0.051725\*** |
| Supportability (from vendor/provider) | **0.049938\*** | 0.053536 |
| Usefulness of visualization | 0.060929 | 0.062425 |
| Variety of data analytics tools / possibilities | 0.063541 | 0.068741 |
| **Max** | **0.078149\*** | **0.079803\*** |
| **Min** | **0.049938\*** | **0.051725\*** |

Calculated weights are graphically represented and shown in Figure 4 below. Values are sorted from the highest to the lowest.

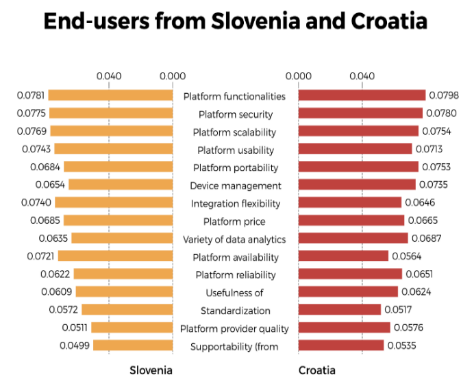
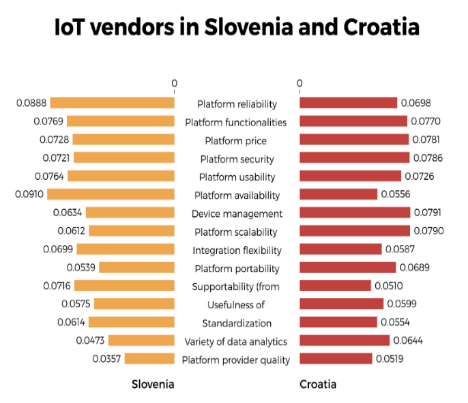


Figure 3. Comparison between Slovenian and Croatian experts

To investigate possible discrepancies and agreement on each criterion, another graphical presentation has been done. The graph shown in Figure 7 presents this study's main results.

Figure 4. Comparison of criteria evaluation

After calculating and analyzing criteria weights for each of the expert groups, it can be concluded that the most similar criteria weights are for (1) *platform functionality, (2) platform security, (3) platform usability, (4) standardization,* and *(5) usefulness of* *visualization*. Opinions that differ the most are the ones from Slovenia vendors. In addition, **platform functionality** was graded above 0.7 by each expert.

DISCUSSION

The goal of this paper was initially to examine criteria weights for the selection IoT platforms according to end-users and vendors and compare the results between Croatia and Slovenia. Accordingly, this research helps to answer the question of *whether differences exist in the perceived importance of IoT platforms' selection criteria between end-users and vendors in Croatia and Slovenia*.

It is interesting to point out that results from end-users in Croatia and Slovenia are very similar. To be precise, they agree on 75% of the top 20% criteria and the least 20% criteria. End-users in Croatia and Slovenia agree on the most important criteria: *functionality*, *scalability* and *security* (each having weight above 0.7). In addition, they also agree on the least important criteria: *standardization* and *supportability* unlike vendors, where when comparing the top 20% criteria and the lowest 20% only one criterion was equally evaluated. Both expert groups grade *vendors' quality and reputation* as the least important ones (lower 20%). Even though the *reliability* of IoT platforms has been highlighted as important (Mashal, Alsaryrah and Chung, 2020), none of the expert groups evaluated it as the most important criteria.

It is also interesting to point out that vendors in Slovenia consider *platform availability* as the most important while Croatian vendors believe it is *device management*. However, when compared to the end-users perspective, it is quite the opposite. Croatian and end-users consider platform *functionality* as the most important criteria.

CONCLUSION

This paper aimed to propose the most important criteria to be considered by relevant end-users when selecting the IoT platform within the Smart City concept. Thus, this paper first identified IoT platform selection criteria based on the literature review. Next, IoT vendors and Smart City managers (end users) have evaluated the proposed criteria according to their importance.

Results have been discussed, and similarities, as well as differences, have been pointed out. When ranking the criteria from largest to lowest one, it can be seen that there is a *considerable difference* between Croatian and Slovenian vendors. However, the difference exists between end-users, but on a smaller scale. The level of agreement between vendors and end-users is graphically presented in Figure 6.

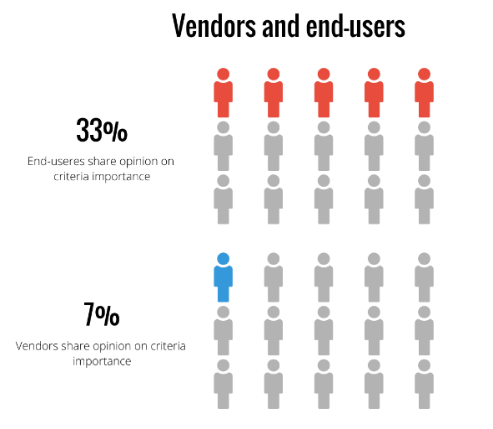


Figure 5. Agreement on IoT criteria between Croatian and Slovenian experts

The grater focus should be put on end-users needs as the user-oriented era becomes more relevant (DeLone and McLean, 2016). The identified *similarities between end-users in Croatia and Slovenia could serve as implications for vendors while developing IoT platforms*. The definite focus should be on platform *functionality*, i.e., how IoT platform uses different features to provide the desired outcome. Besides *functionalities*, vendors need to focus on *scalability*, *security*, and *usability*. These results are particularly important and should be used as a reference since, for example, *scalability* is ranked as only 11th (out of 15 criteria) among Slovenian vendors. At the same time, other experts agree on its importance.

To conclude, both can use the results of this study, IoT vendors to better tail the needs of the end-users when designing future IoT platforms, and Smart City administrators, managers, and policy planners when selecting the IoT platforms for the Smart Cities.

The presented study suffers from a few **limitations**, which can also serve as starting points for future research. As demonstrated in the results, the evaluated weights that differ the most are the ones from *Slovenia vendors*. It could be interesting to examine some demographic characteristics of experts to explore whether this impacted grades received. Therefore it is crucial to study experts' characteristics factors. The authors used a more generic approach since they could not define selection criteria for specific cities or specific IoT platforms. In the future, MCDM methods (such as the Analytical Hierarchal Process, the Analytical Network Process, Data Envelopment Analysis (DEA) or PROMETHEE (Barzman *et al.*, 2021)) could be used to verify the results and to select the IoT platform on an actual case study

Because this study is based on a survey, measuring mistakes such as the number of respondents and the type of questionnaire utilized can occur and therefore present another limitation. Limitations regarding the small number of experts should be addressed by conducting another study with a more significant number of end-users. In addition, even tho experts could add criteria, none of the additional criteria was yielded. Hence, more IoT selection criteria could be included in the analysis with a more detailed approach – sub-criteria perspective. For example, a recent study used *energy consumption* as one of the criteria for smart object selection (Mashal, Alsaryrah and Chung, 2020); however, this study has not included it, so future research should examine and explore novel criteria to ensure sustainable development of IoT platforms.

# Acknowledgment

This work has been supported by the Croatian Science Foundation (grant number UIP-2017-05-7625) and the bilateral scientific project Comparative Analysis of Trends and Success Factors for Smart Cities Development in Slovenia and Croatia.

References

1. Abdelghaffar, H., Abousteit, M. (2021). Internet of Things (IoT) interoperability success criteria. *International Journal of Enterprise Information Systems*, 17(1), pp. 85–105. doi: 10.4018/IJEIS.2021010105.
2. Abdelmegid, M. A., Gonzalez, V. A., Poshdar, M., O'Sullivan, M., Walker, C. G., Ying, F. (2020). Barriers to adopting simulation modelling in construction industry. *Automation in Construction*. Elsevier, 111(June 2019), p. 103046. doi: 10.1016/j.autcon.2019.103046.
3. Alelaiwi, A. (2019). Evaluating distributed IoT databases for edge/cloud platforms using the analytic hierarchy process. *Journal of Parallel and Distributed Computing*. Elsevier Inc., 124, pp. 41–46. doi: 10.1016/j.jpdc.2018.10.008.
4. Babić, Z. (2017). *Modeli i metode poslovnog odlučivanja*. Split: Sveučilište u Splitu, Ekonomski fakultet.
5. Barzman, M. et al. (2021). Exploring Digital Transformation in Higher Education and Research via Scenarios. *Journal of Futures Studies*. Tamkang University, 25(3), pp. 65–78. doi: 10.6531/JFS.202103\\_25(3).0006.
6. Baumgärtner, S. and Winkler, R. (2003). Markets, technology and environmental regulation: Price ambivalence of waste paper in Germany. *Ecological Economics*, 47, pp. 183–195. doi: 10.1016/S0921-8009(03)00194-0.
7. Contreras-Masse, R., Ochoa-Zezzatti, A., Garcia, V., Elizondo, M. (2019). Selection of IoT Platform with Multi-Criteria Analysis: Defining Criteria and Experts to Interview. *Research in Computing Science*, 148(11), pp. 9–19. doi: 10.13053/rcs-148-11-1.
8. DeLone, W. H., McLean, E. R. (2016). *Information Systems Success Measurement, Foundations and Trends® in Information Systems*. doi: 10.1561/2900000005.
9. EK (2020). What are smart cities?. European Commission. Available at: https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities\_en.
10. Gartner (2020). Gartner Says Government IoT Revenue for Endpoint Electronics and Communications to Total $15 Billion in 2020. Available at: https://gtnr.it/2Tt0Ivj.
11. Kim, Suwon and Kim, Seongcheol (2016). A multi-criteria approach toward discovering killer IoT application in Korea. *Technological Forecasting and Social Change*. Elsevier Inc., 102, pp. 143–155. doi: 10.1016/j.techfore.2015.05.007.
12. Kim, T., Ramos, C., Mohammed, S. (2017). Smart City and IoT. *Future Generation Computer Systems*. Elsevier B.V., 76(July 2014), pp. 159–162. doi: 10.1016/j.future.2017.03.034.
13. Kondratenko, Y., Kondratenko, G., Sidenko, I. (2018). Multi-criteria decision making for selecting a rational IoT platform. *Proceedings of 2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies, DESSERT 2018*. IEEE, pp. 147–152. doi: 10.1109/DESSERT.2018.8409117.
14. Kondratenko, Y., Kondratenko, G., Sidenko, I. (2019). Multi-criteria decision making and soft computing for the selection of specialized IoT platform. *Advances in Intelligent Systems and Computing*. doi: 10.1007/978-3-319-97885-7\_8.
15. Lin, M., Huang, C., Xu, Z., Chen, R. (2020). Evaluating IoT Platforms Using Integrated Probabilistic Linguistic MCDM Method. *IEEE Internet of Things Journal*, 7(11), pp. 11195–11208. doi: 10.1109/JIOT.2020.2997133.
16. Mashal, I., Alsaryrah, O., Chung, T. Y. (2020). A multi-criteria analysis for an internet of things application recommendation system. *Technology in Society*. Elsevier Ltd, 60(October 2019), p. 101216. doi: 10.1016/j.techsoc.2019.101216.
17. Mijač, T., Ninčević Pašalić, I., Tomat, L. (2021). SELECTION OF IOT PLATFORMS IN SMART CITIES: MULTICRITERIA DECISION MAKING. *Proceedings of the 16th International Symposium on Operational Research in Slovenia*, pp. 35–40.
18. Ninčević Pašalić, I., Jadrić, M., Ćukušić, M. (2020). E-Participation Tools Used by City Governments in Croatia. *Proceedings of FEB Zagreb 11th International Odyssey Conference on Economics and Business*.
19. Nižetić, S., Šolić, P., López-de-Ipiña González-de-Artaza, D., Patrona, L. (2020). Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. *Journal of ckeaner production*, 274(January).
20. Nunes, L. H., Estrella, J. C., Perera, C., Reiff-Marganiec, S., Botazzo Delbem,, A. C. (2017). Multi-criteria IoT resource discovery: a comparative analysis. *Software - Practice and Experience*, 47(10), pp. 1325–1341. doi: 10.1002/spe.2469.
21. Pušnik, M., Pavlinek, M., Šumak, B., Kous, K. (2019). Analysis of Characteristics of Urban Communities in Slovenia for Smart City Development. *Proceedings of the European Conference on Information and Intelligent Systems*, pp. 143–147. Available at: http://archive.ceciis.foi.hr/app/public/conferences/2019/Proceedings/ICTEI/ICTEI1.pdf.
22. Silva, E. M., Jardim-Goncalves, R. (2017). Multi-criteria analysis and decision methodology for the selection of Internet-of-Things hardware platforms. *IFIP Advances in Information and Communication Technology*, 499, pp. 111–121. doi: 10.1007/978-3-319-56077-9\_10.
23. Silva, E. M., Jardim-Goncalves, R. (2021). ‘Cyber-Physical Systems: a multi-criteria assessment for Internet-of-Things (IoT) systems. *Enterprise Information Systems*. Taylor & Francis, 15(3), pp. 332–351. doi: 10.1080/17517575.2019.1698060.
24. Singla, C., Mahajan, N., Kaushal, S., Verma, A., Kumar Sangaiah, A. (2018). Modelling and analysis of multi-objective service selection scheme in iot-cloud environment. *Lecture Notes on Data Engineering and Communications Technologies*, 14, pp. 63–77. doi: 10.1007/978-3-319-70688-7\_3.
25. Thomas, M. O., Onyimbo, B. A., Logeswaran, R. (2016). Usability Evaluation Criteria for Internet of Things. *International Journal of Information Technology and Computer Science*, 8(12), pp. 10–18. doi: 10.5815/ijitcs.2016.12.02.
26. Uslu, B., Eren, T., Gür, S., özcan, e. (2019). Evaluation of the Difficulties in the Internet of Things (IoT) with Multi-Criteria Decision-Making. *Processes*, 7(3). doi: 10.3390/PR7030164.

**Developing a Conceptual Model for Sustainable Transport Infrastructure Planning: A System Thinking Approach and Preliminary Dynamic Modeling**

Introduction

In 1987, the Report of the World Commission for Environment and Development (WCED, 1987) described sustainable development as development that meets the needs of the present generation without compromising the ability of the upcoming generations to meet their own needs. Despite its short history, sustainable development is considered to be a multidisciplinary concept that influences many economic, social, and environmental prospects (Shao, Li, Tang, 2011). Goldman and Gorham (2006) suggest that sustainable development is effective and reliable concept due to its intuitive policy and flexible framework to adapt alongside economic and environmental challenges and social aspirations. Although the main pillars of sustainable development are economic, environmental, and social forms of capital (Elliot, 2013:20; Harris, 2000; Giddings, Hopwood, O'Brien, 2002) and their interactions (Gonzalez-Feliu, 2018:45), some authors extend the concept by adding ethical, technological, political, and other forms of capital (Pawlowski, 2009; Lankauskiene, Tvaronaviciene, 2012). According to Cheba and Saniuk (2016), evolving economic, environmental, and social requirements are primary challenges for sustainable urban logistics as an integral part of urban development. Banister and Lichfield (1995:1) added that urban attractiveness, often treated as an important issue for efficient urban mobility and transportation, largely depends on relative accessibility, which relies on the quality of transport infrastructure. Similarly, different sources presented in Cheba and Saniuk (2016) emphasize the correlation between urban accessibility and level of infrastructure development and its economic and social potential. Therefore, transport infrastructure investments are commonly seen as a critical catalyst in the process of urban development (Lee et al., 2020), enabling higher urban mobility performance and transportation of people, goods, services, and information from one location to another (Rodrigue, Comtois, Slack, 2013:1). With the undeniable influence on a city's sustainable development (Shen et al., 2018) and urban population growth (United Nations, 2019), expectations for a more effective, supportive, and sustainable transport system are evolving (Shen et al., 2018; Ngossaha et al., 2018). Accordingly, transport infrastructure has become an integral part of urban development strategies (Badada Badassa, Sun, Qiao, 2020) since no economic or social sector is independent of the transport system performance (Morchadze, Rusadze, 2018).

Considering the significance of urban mobility in sustainable development (Cheba, Saniuk, 2016; Skorobogatova, Kuzmina-Merlino, 2017) and the importance of transportation and environmental planning for urban growth (Waddel, 2002), many authors found simulation modeling to be appropriate in managing various aspects of the field (Hosseinali, Alesheikh, Nourian, 2013; Kekez, Jadrić, Ćukušić, 2021). Simulation modeling is used frequently as a reliable tool for urban mobility management (Ćukušić, Jadrić, Mijač, 2019), making system complexity, types of problems, and decision-maker requirements main factors for the choice of a suitable modeling approach (Currie et al., 2020). Since transportation system is a complex field of research with multiple system variables, relations, and loops, system thinking and system dynamics are considered appropriate approaches to describe system behavior, characteristics, and variable connections (Suryani et al., 2022; Wang, Lu, Peng, 2008). As an introductory to system dynamics modeling, system thinking is a causal approach that describes the relationships between system variables using causal loop diagrams as a supportive building mechanism for further model development (Suryani et al., 2022).

Based on the above premises, this paper applies system thinking and preliminary dynamic modeling to create a conceptual basis for further simulations of various transport infrastructure strategies, identify the impact of different scenarios on urban mobility, and utilize system thinking in a complex environment such as a transport system. System thinking often relies on subjective intuition for evaluating the complex structures that emerge from the initial observation of the real-world system (Forrester, 1994), supporting the ability to understand how real-world system operates (Sterman, 2002). Furthermore, Sterman (2002) added that a holistic view of real-world systems facilitates faster and more effective learning and helps in making better long-term decisions. Theoretical and practical similarities and differences between system thinking and system dynamics are presented in Richmond (1994), but it is necessary to understand that systemic thinking is not quite the same as system dynamics, although it overlaps in many areas. In order to contribute a better perspective of both terms and this paper, system thinking is attached to conceptual modeling of causal loop diagrams, and system dynamics involve building and simulation of conceptual models using machine language in an appropriate simulation modeling tool. Consequently, the study evaluates suggested approaches as vital for reliable system build-up, taking both methodology advantages and disadvantages into consideration. The above-mentioned indicates that the study is considerably inspired by the described methodologies and their usage in sustainable transportation and urban development fields. Finally, this paper primarily aims toward system thinking and problem modeling rather than suggesting definitive transport solutions to reform the performance of its activities, indicating the presence of potential opportunities for further research within the case study area. The remainder of this paper is organized as follows: Literature background on urban sustainability, transport infrastructure planning, and corresponding methodologies is elaborated in section 2. Section 3 dives deeper into the research mechanism of system thinking and modeling. Section 4 introduces a case study of East Coast Split. Section 5 presents the results in conceptual system modeling of causal loop diagrams and dynamic preliminary modeling. Finally, section 6 draws a conclusion to the study with future directions for dynamic sub-modeling simulations to analyze the effectiveness of different infrastructure strategies for urban sustainability, traffic efficiency, and mobility.

Literature review

*Transport infrastructure and urban development*

Population growth and increased migrations in urban areas correlated with transport congestion and decreased efficiency of urban mobility are driving demand for many transport infrastructure projects (Nguyen, Cook, Ireland, 2017). Transport infrastructure regulates mobility, determines transportation landscape architecture, influences trade flows, and affects various social assets of urban residence (Short, Koop, 2005). As discussed in Saidi et al. (2020), the growing impact of transportation on regional development pushes governments to increase infrastructure investments in order to achieve the long-term sustainability of transport systems and stimulate economic growth. Results correspond with sustainable policies to develop effective urban logistics while taking care of congestion reduction and negative environmental consequences. Moreover, investments in urban transport infrastructure are often the heart of efforts to trigger economic growth, as it is considered that insufficient quality of proper infrastructure is a constraint for numerous countries (Alder, 2015). Although mentioned studies portrayed that investments in transport infrastructure have a significant impact on urban economic development, some authors argue that transport infrastructure by itself is not sufficient for favorable sustainable outcomes. More specifically, Crescenzi and Rodriguez-Pose (2012) investigated the relationship between transport infrastructure investments and regional growth in the European Union (EU-15) from 1990 to 2004 and concluded there is no significant evidence that European transport investment policies largely contribute regional development. Furthermore, Elburz, Nijkamp, and Pels (2017) discovered a disparity in the outcomes of a various infrastructure investments for specific countries and regions with different levels of development (*research included three categories: USA, Europe and 'Others'*). The authors concluded that differences in research methodology, techniques, data type and measurements, research period, observed areas, and its characteristics, play a prominent role in obtaining positive or negative study outcomes, thereby can influence final observations and conclusions. In addition, it is possible to call upon the fact that most of the regional transport infrastructure projects require large land areas and long-term investments, and often due to its scope and schedules, the project cycle stretches over the years or even decades, making it harder to evaluate. Interestingly enough, results shown in Hong, Chu, Wang (2011) correlate with the mentioned discoveries in Elburz, Nijkamp, Pels (2017), where it is found that infrastructure investments contribute differently within particular regions of China, especially those including land transport infrastructure. The lower starting infrastructure quality is, the higher impact on economic development delivers. Xueliang (2013) complements the conclusions on transport infrastructure investments using China as a research subject, noting that infrastructure investments, including investments in transport infrastructure, should focus on the spatial efficiency in specific areas of regions. Therefore, many researchers complemented these conclusions using mathematical and simulation modeling techniques in their studies in order to evaluate and predict different land-use implications (Shen et al., 2009; Zheng et al., 2012; Geng, Zheng, Fu, 2017). This may include spatial changes at a macro scale (such as planning new urban transport system; *e.g., creation of new urban center*) or at a micro scale (local infrastructure projects; e.g., transport infrastructure rearrangement – *such as* *case study East Coast Split*) (Lee et al., 2020).

*Sustainable urban logistics and the Smart City*

As urban logistics has a considerable influence on the quality of life, a variety of sustainable transportation topics within the Smart City concept are becoming increasingly popular among researchers (Koglin, 2017; Benevolo, Dameri, D'Auria, 2016). Sustainable urban development and the Smart City concept represent growth paradigms that emerged as a result of the drive of cities to be more responsive to citizen requirements, elevate a higher quality of life, and enhance competitiveness in an increasingly globalized environment (Angelidou et al., 2017). Additionally, making a city *smart* is an innovative way to reduce the problems caused by urban population growth and fast-paced urbanization (Chourabi et al., 2012). Rapid population growth and urban migrations are causing many technical and infrastructure problems, lowering the city's functionality and decreasing citizens' quality of life (Gil-Garcia, Pardo, Nam, 2015). However, cities can only be *smart* and *sustainable* if there are adequate technological solutions that can integrate and synthesize data collected through multiple sources regarding the movements of people, goods, and information about the physical and social form of the city (Batty et al., 2012). Due to the popularity of the concept and its elements, different interpretations may appear among various research areas (Ninčević, Ćukušić, Jadrić, 2020), including urban planning and transport system development. Hall et al. (2000) shared its vision of a *smart* city and its infrastructure as: *„A city that monitors and integrates conditions of all of its critical infrastructure, including roads, bridges, tunnels, railways, airports, seaports, etc., can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens*.“ Likewise, Harrison et al. (2010) combine different infrastructure elements, including transport infrastructure, to leverage the city's intelligence. Additionally, besides urban infrastructure and comparable to earlier Banister and Lichfield's (1995) statement, Giffinger et al. (2007) emphasize the importance of urban accessibility for city development as well as the availability of ICT and sustainable transport systems, all under the framework of Smart City and Smart Mobility. Alongside infrastructure-oriented topics, Smart Mobility also investigates a variety of issues specific to traffic management strategies, vehicle tracking, security in transport (Ismagilova et al., 2019) and encourages sustainable development by optimizing transport services while taking into consideration its economic, social, and environmental challenges (Zawieska, Pieriegud, 2018).

*System thinking and dynamic modeling for transport infrastructure planning*

Compared with traditional qualitative and quantitative methods for transport infrastructure analysis and transport systems in general, system thinking helps conceptualize the relations among system variables, while system dynamics quantifies them through the building of dynamic differential equations using simulation tools (Xue et al., 2020). As a research methodology, the concept of system dynamics developed from a system theory in the business management field during the late 1950s under Jay Forrester at the Massachusetts Institute of Technology (Wolstenholme, 1982), and over the years, expanded its research areas at an exponential rate (Forrester, 1994), including urban studies, transport systems and infrastructure (Shepherd, 2014). Some of the previously cited studies in this section successfully adopted and presented a system dynamics approach to simulate and validate the consequences of different land-use strategies, including land transportation, but additionally revealed an absence of transport infrastructure planning in the process. Simulation planning with system dynamics enables 'what-if' scenario experiments which is a valuable complementary technique to the infrastructure project management due to its ability to incorporate the more subjective factors within causal loop diagrams and 'communicate' the relations between system variables of infrastructure projects (Rodrigues, Bowers, 1996; Richardson, Otto, 2008). Additionally, system dynamics is considered to be a convenient tool for risk management in infrastructure project development due to a lack of systematic approaches and instruments for identifying and expressing the interactions among economic, social, and environmental challenges in project development (Boateng et al., 2012). Therefore, many authors identified research potential between transport infrastructure planning, land-use strategies, system thinking, and dynamics modeling and, consequently, provided additional research literature in order to support sustainable development and infrastructure project management. Haghshenas, Vaziri, and Gholamialam (2014) developed a dynamic transportation model using system thinking and dynamics in order to analyze different sustainable transportation policies. System analysis and model development included sustainable transportation indicators, trip generation module, and both private and public transport infrastructure capacities. Jiang, Li and Xu (2010) used a system dynamics approach to estimate the impacts of different transport infrastructure investments on tourism development and revenues from tourism activities in the particular regions of China. Nguyen, Cook, and Ireland (2017) combined system dynamics with cost-benefit analysis in order to evaluate the economic and social impacts of transport infrastructure investments and estimate possible outcomes of different scenarios. Similarly, Wang et al. (2018) estimated the influence of transport infrastructure investments on the regional economy and employment rate to help the policymakers evaluate the possible outcomes of different strategies. The authors concluded that system dynamics modeling is an appropriate technique for transport infrastructure planning, and it can be effective in economic forecasting and analytics. In order to achieve promising sustainability performance in transportation, Shen et al. (2018) implemented a dynamic model to investigate sustainable policies for transportation development and mobility performance in an urban area. The study included both transport demand and infrastructure supply to support day-to-day urban activities and development on a macro scale. In addition, some authors combined system dynamics and transportation planning for urban mobility improvement, including infrastructure capacity expansion and its influence on urban sustainability (Wang, Lu, Peng, 2008; Noto, 2017). More specifically, Wang, Lu, and Peng's (2008) simulation process included a subsystem modeling approach divided into seven related submodels of an urban transport system focusing on vehicle policy and its effects on urban development. Considering the demonstrated insights, it is possible to conclude that transport modeling deals with an increased number of system interactions simultaneously, making system thinking inevitable in the process.

Research methodology

This study combines the system thinking and dynamics modeling approach into a mutual format, focusing primarily on conceptual modeling of a complex system in order to set a valuable basis for further infrastructure capacity analysis and performance estimation under particular sustainable and transportation challenges in the area. Thus, both methodologies are taken into model development since they are part of a system theory and are complementary to each other. At this stage, the research approach implies the dynamic hypothesis elaboration that requires the creation of a dynamic model that will consider the conceptual foundation built under the scope of this research in further testing. Within this framework, system dynamics is a methodology that applies different methods and tools to support system thinking, facilitate modeling, analysis and learning about real-world problems, structures and processes (Forrester, 1961; Sterman, 2001; Goh, Love, 2012). Simulated models are 'representative' or 'substitute' structures of a real-world system they represent (Mäki, 2005), defined by a set of statements about a targeted system (Seidewitz, 2003). However, no matter how much in detail a real-world system can be examined, it is impossible to identify all system variables and their relationships (*hidden loops*) that affect system behavior (Richardson, 1986). Furthermore, it is not recommended to make overly detailed system model due to its potential underperforming and impracticalities working with extensive models. Additionally, the system modeling is not a time-definitive process but an indefinite one since many system changes affect its structure evolution, causing it to grow over time, adding difficulties to analyze, and providing new system insights to the system analysts. Even if most of the variables are inactive, the remaining active system variables form a new system structure with different practices and rules. Therefore, a good model is a tradeoff between realism and simplicity (Maria, 1997).

The process of systems modeling consists of two main procedures: causal loop modeling (*system thinking*) and stock-flow modeling (*system dynamics*) – this study focuses mainly on system thinking. Forrester (2009) specifies that all system activities are closed-loop structures, a network of feedback loops where every action or change generates some return. These feedbacks present a fundamental step in designing the dynamic hypothesis using system thinking. Furthermore, feedback loops can be: positive - generating value increase on primary system variable (Reinforcing loop), negative – generating value decrease on primary system variable (Balancing loop), time delay – feedback with system delay on return. Time delays are a specific feedback channel due to their long-run response nature (Sterman, 2002), whether considering the time needed for the system to tradeoff primary intervention or given time to stabilize around its average values.

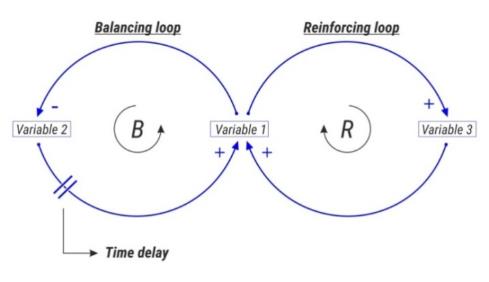


Figure 1. *Causal loop diagram* (Yu et al., 2014)

Stock-flow model is built out of three types of variables: stock, rate and auxiliary variables, and two types of flows, material and information flow. System variables, together with material and information flow, create the basic structure of a dynamic system (Shen et al., 2009). The ability to describe dynamic processes continuously with time delays and study cumulative system changes makes system dynamics a worthy approach for various sustainable development issues (Xue et al., 2020) as well as transportation-oriented topics (Coyle, 1996). Simplified, the stock is a resource accumulation changed in time (t) and by a rate determined in a flow. How flow operates is defined with an operational statement (*syntatic rule*) controlled by a current state of stock in comparison to a system's goals (Forrester, 2009). In a given interval of system simulation, the flow controls the ongoing (accumulated) state (value) of stock by changing its system behavior (oscillations) from positive (increase) to negative (decrease) and vice versa (or strictly positive or negative system accumulation), or system stabilization around goal-seeking values (Sterman, 2000: 107-133). Patterns of behavior are accumulated in time on the stock and can be affected by different inflow rates that can be hidden or shown in the final system model. Therefore, adding a time interval is essential for the dynamic nature of system dynamics models as differential equations calculate the rate of a system change continuously during the specified time interval (t(0) – t(n)).  A mathematical relationship between stock and flow can be expressed by the equation:



where: (1) **S(t)** – accumuliated stock value in time (t); (2) **S(0)** – the initial stock value; (3) **F*in\_flow*(t)** and **F*out\_flow*(t)** – a differential flow in time (t). The remaining system (auxiliary) variables help calculate the flows or communicate the stages of the calculation process (Caponio et al., 2015).

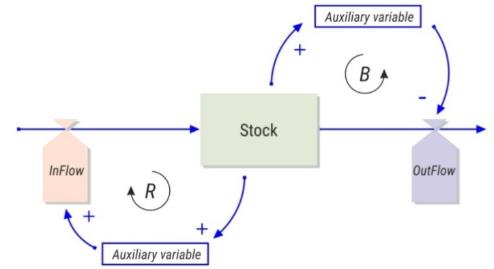


Figure 2. *Causal loop diagram displaying stock and flow structure* (Author's drawing based on Sterman, 2001; Yu et al., 2014)

Case study

According to local authorities reviews (City of Split, 2005), the future development of a city largely relies on the quality of transport infrastructure and the ability to meet growing transport demand, especially those initiated in the tourist season during summer months. The logistics role of the city in local and regional transportation is determined by its geographic position and the fact that the city of Split is the largest regional center on the eastern side of the Adriatic Sea coast (Tourist Board of the City of Split, 2017; City of Split, 2005). East Coast Area, which is located near the city center and on the eastern side of a city riviera, holds the vital logistic function of the city and the local community. The mentioned location comprises different private and public transportation options whose transport infrastructure capacities are divided into three functional areas: (1) Road infrastructure, (2) Rail infrastructure, (3) Port infrastructure.



Figure 3. *Land transport infrastructure area – East Coast Split*, *Google Maps* (Author's work)

According to the urban master plan document (European Bank for Reconstruction and Development, 2020), land ownership and size is divided between (1) Port Authorities - 95.900 m[2], (2) Croatian Railways - 42.900 m[2], (3) the city of Split - 32.500 m[2], (4) Private property - 21.000 m[2], (5) the Republic of Croatia - 6.700 m[2]. These areas total approximately 199.000 m[2] of land space. For its transport purpose and functionality, area is divided as follows: (1) Road infrastructure - 32.500 m[2], (2) Rail infrastructure m[2] - 42.900 m[2], Port infrastructure - 95,900 m[2], (4) Remaining land infrastructure with unspecified transport purpose - 27.700 m[2]. Due to the seasonal traffic congestion, the idea of recently proposed transport guidelines is to reduce some types of transport (i.e., strategic relocation to the area of Kopilica - Split), which would eventually result in numerous positive impacts on transportation and urban sustainability in general. Besides active transport activities on the East Coast Area, a significant issue presents entrance to the different transport modes located on the land area during the summer months. Additionally, public infrastructure capacities are insufficient for the proper transport mobility performance of the local community (Institute for Development and International Relations, 2019). Currently, the observed transport system is off-balance since there are types of transport with low infrastructure resources and high transport demand (road infrastructure) while others have lower requirements and increased available infrastructure resources (rail infrastructure), causing them to be inefficient in reverse - low usage rate (European Bank for Reconstruction and Development, 2020).

System Structure and Causal Loop Development

After determining the scope of the research methodologies and setting up the theoretical basis required for the system understanding, the next step is to create a conceptual model, starting with a system assumption relation. Urban transport mobility is displayed as a relationship between transport supply and demand, continuously observed in the experimental time interval t(0) - t(n), where system stock (state) is a sum of an initial system state t(0) and accumulative state over time ∆t(0-n):



Therefore, the stock value at t(0) is not an integrated part of the ∆t(0-n) expression, but the initial time unit of the simulation flow from t(0) — not including to t(n) — encloses at the end of the simulation process. Methodologically, the reason for given form (*and not t(1)*) is in the characteristic of continuous simulations to describe the dynamics of real-world processes during the entire simulation process where there are no predetermined simulation time units (*excluding start and end of simulation process – t (0) and t (n)*). Continuous simulations track the system behavior through the duration of the simulation run, while events in sequenced time intervals (*e.g., t(1), t(2) - t(n)*) are features of discrete-event simulations where the system state between particular events remains stable. Transport supply represents the capacity of available transport infrastructure of the area in the time interval, while transport demand refers to the number of system 'population' (*system entities*) in the transportation network with identified transportation needs over the equivalent time interval. Therefore, it is possible to distinguish the two main principles of transport mobility. (1) Effectiveness - the transport service is (is not) realized regardless of assigned time interval; (2) Efficiency - the service is (is not) performed within a specified time interval, under specific conditions, optimized and cost-effective. In addition, transport infrastructure planning requires the differentiation of two terms used in this study, infrastructure performance estimation and available infrastructure capacities. Infrastructure capacity is the highest obtainable practical value of a selected infrastructure resource in a particular time unit or time interval. Infrastructure performance estimation is a potentially achievable (*sustainable*) value (*benefit*) of added infrastructure investments. The added infrastructure investments may or may not be in order to improve infrastructure capacity and reach the estimated infrastructure performance, as each unit of infrastructure resource is restricted by its diverse conditions and boundaries of the observed area (geographical, ecological, social, etc. Infrastructure investments whose capacities have reached the highest achievable infrastructure performance are often maintenance costs or similar expenses. Additionally, the East Coast Area has a large-scale of other system variables (not solely transportation-oriented variables); therefore, it is impractical to allocate all investments into one infrastructure resource in order to achieve the highest estimated infrastructure performance, as this would imply the exclusion of all remaining transport infrastructure facilities which are in service of area mobility and other economic, environmental, and social requirements of the area.

According to available data (Tourist Board of the City of Split, 2017), tourist arrivals are a dominant factor determining a demand for transport services during the summer months, but not the only one. The population also consists of passengers and locals who utilize the available infrastructure resources for mobility services. Terminologically, a passenger who activates available infrastructure resource can be a tourist or a local individual. According to a World Tourism Organization (n.d.), a tourist is a visitor (domestic or foreign) if their visit includes an overnight stay or a one-day trip. Therefore, a tourist is a type of passenger, while tourism is a subset of travel as it refers to the individuals who move between geographical locations regardless of its purpose or duration. Furthermore, the system 'population' entity does not have to be exclusively a person but can be a vehicle or other form of motorized and non-motorized transportation. They perform differently and have different infrastructure requirements and mobility purposes. All together, they form a system population of the model expressed as follows:



In theory, economic development influences transport demand and attracts more population migrations (Wang, Lu, Peng, 2008). The urban population migrations also reflect on tourist arrivals (Griffin, Dimanche, 2017), which causes an increase in demand for transport services, creating additional pressure on transport supply — infrastructure capacity. If the local authorities (government) can't respond to the transport demand requirements by suppling enough transport infrastructure resources, that could lower urban transport mobility and discourage additional economic activities. Considering that economic development positively correlates with population migrations in the long run (including vehicle-owning policies) and a decrease of urban mobility performance negatively affects economic growth, possible consequences could lead to a system population loss over time. Hypothetically speaking, a causal relation between urban mobility effectiveness and economic development is positive because the growth of one variable on average causes the increase of another and vice versa. However, an increase in transport demand also brings up some undesirable consequences that are negatively causal with economic development, such as ecological and social issues. In other words, if the population growth causes an increase in traffic demand, then, consequently, negatively affects the congestion on the land area – insufficient infrastructure capacity contributes to gas emissions growth (air pollution) in transport, noise increase, etc (Suryani et al., 2022).

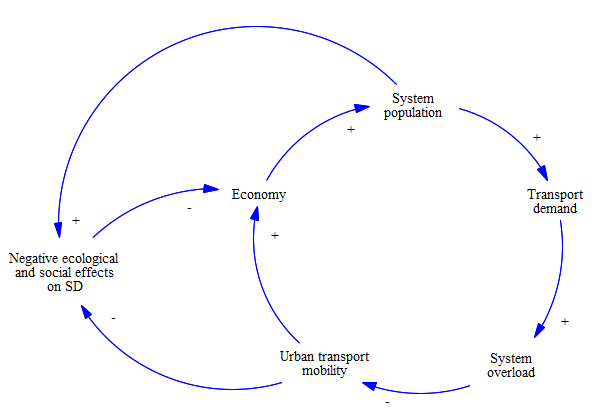


Figure 4. *Introductory causal loop diagram of a transport system relations* (Author's work)

Furthermore, due to the advantages and disadvantages of higher transport demand, the accumulated state of system stock affects the economy, illustrated as a gross domestic product (GDP) in the conceptual model (Figure 5.), whose rates determine added transport infrastructure investments. The higher GDP rates are, the more added investments there will be (Wang et al., 2018). By default, added transport infrastructure investments enhance transport effectiveness and efficiency (i.e., decreasing time delays in the system, achieving more system entrances, reducing infrastructure occupation and mobility dropdown rates, etc.). Additionally, as urban mobility policies include a variety of sustainable development aspects (i.e., ecological challenges), added infrastructure investments should also stimulate investments in a public (sustainable) infrastructure and correspondingly reduce the possibility for unwanted outcomes due to the higher transport demand. The rearrangement of private transport infrastructure and rethinking implementation of public forms of transportation contributes significantly to pollution reduction and helps reduce traffic congestion (Titos et al., 2015; Xue et al., 2020).

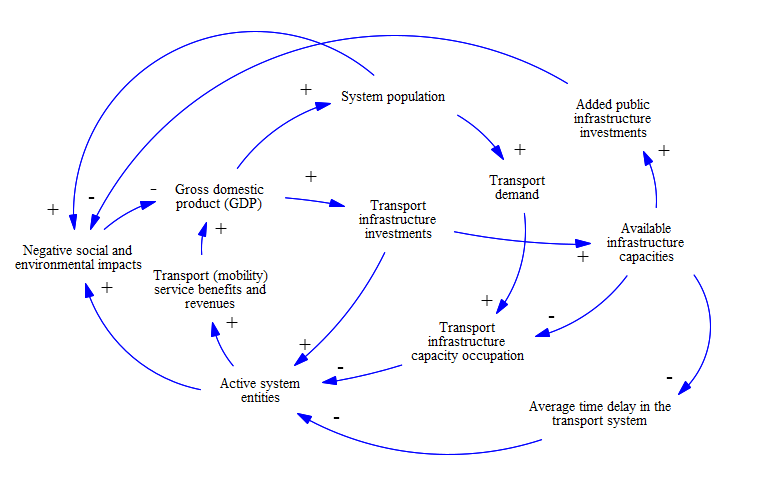


Figure 5. *The first extension of a causal loop model of a transport system* (Author's work)

Figure 5 presents the first extension of a conceptual model. In short, the system population increases the transport demand where one registered entity arrival can occupy one or more transport infrastructure resources (capacities). The higher transport demand is, the more pressure on infrastructure capacities will deliver, consequently lowering available infrastructure capacities over time. Upon infrastructure capacity occupation, system individual (entity) generates: (1) Positive effects such as revenues from transport services within the area (returns are not necessarily financially oriented - these can include a variety of desirable short-term or long-term effects on the sustainable development achieved by economic and transport activities); (2) Negative effects such as increased gas emissions for motorized vehicles, waste generation, traffic noise, etc. The accumulated change in time reflects on the GDP stock balance used as an economic state indicator to perform added infrastructure investments, prioritizing sustainable alternatives in the transport system. Furthermore, the GDP balance change also operates as an economic indicator for evaluating the tendency of the vehicles policies in the transport system as well as other system variables in follow-up such as population migrations, tourist arrivals, etc. Therefore, both system population and infrastructure capacities are affected by the economic oscillation in a model, leaving local authorities and analysts to determine guidelines for managing urban mobility as a relationship between supply and demand for transport services, also considering infrastructural boundaries of the area and urban sustainability goals.

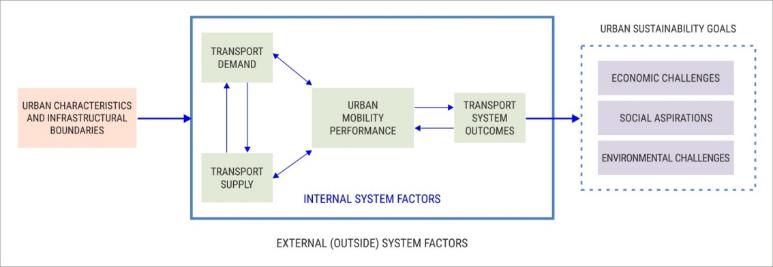
****

Figure 6. *Transport system factors* (Author's drawing based on Haghshenas, Vaziri, Gholamialam, 2015; Haraldsson, 2004)

Shen et al. (2018) suggested it is more suitable to work with transport supply (infrastructure capacities) in operating transport performance by analyzing impacts of transport infrastructure investments and evaluating infrastructure capacities. In order to experiment with infrastructure capacities and estimate its potential, Nguyen, Cook, and Ireland (2017) defined transport congestion (system overload) in time unit (t) as:



where: (1) **Active system entities(t)** - amount of actual transport demand (*system population*) in time unit (t); (2) **Transport infrastructure capacity(t)** - available transport infrastructure capacities in equivalent time unit (t). Bernardino and van der Hoofd (2013) extended the earlier equation by adding dynamic value and describing transport congestion as a relation between aggregate transport (*system*) flow and average population (*entity*) speed:



where: (1) **s** – average entity speed in the transport system; (2) **s(0)** – average free flow speed in the transport system; (3) **Q(a)** – average traffic flow (entities/day); (4) **C(b)** – aggregate infrastructure capacity parameter; (5) **α, β** – model calibration parameters. In order to estimate available transport infrastructure capacities, Ojha et al. (2018) formed qualitative and quantitative model representation using road infrastructure capacities as a research topic. The model includes various road infrastructure factors that directly affect available infrastructure capacities such as (1) Connectivity Issues (**Tci**) – infrastructure capacity loss due to the connectivity issues caused by external and internal system factors; (2) Infrastructure Maintenance (**Tim**) – short-term temporary infrastructure capacity loss due to the ongoing maintenance; (3) Traffic Jams (**Tpz**) – temporary infrastructure capacity loss due to the transport congestion (system overload) or traffic accidents; (4) Infrastructure Construction (**Tgp**) – permanently or temporary infrastructure capacity loss with potentially long-term duration due to the infrastructure investments/projects or infrastructure conversion into other facilities; (5) Infrastructure for Special and Emergency Causes and Transport Modes (**Tpop**) – permanently infrastructure capacity loss due to the specific requirements or other transport mobility purposes that are not directly linked to the traffic-related services.

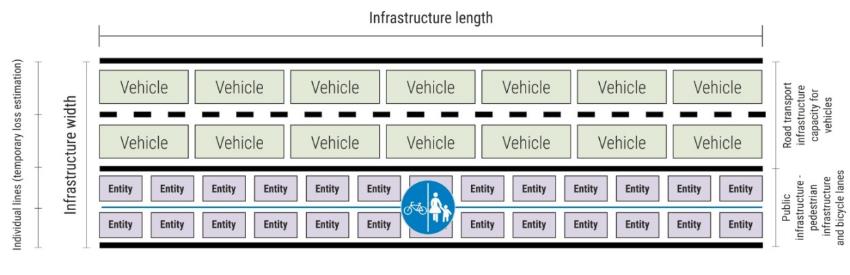


Figure 7. *Road (public) infrastructure capacities estimation* (Author's drawing based on Ojha et al., 2018)

Another type of infrastructure loss includes 'spatial' loss due to security distance (**Tsu**) estimation between entities or system boundaries that equals the minimum estimated percentage needed for a security distance between the system population in traffic.

The aggregate of the permanently lost, temporarily closed, and security distanced infrastructure represent total infrastructure capacity loss (**Tuk** = *Tci + Tim + Tpz + Tgp + Tpop + Tsu*).

Finally, **the available** (**net**) **infrastructure capacities** are equal to the 'remainder' of the estimated total infrastructure capacity loss (Tuk) subtracted from the infrastructure capacity of the area:

***Available (net) infrastructure capacities*** *=**Transport infrastructure capacity – T(uk)****;***

where transport infrastructure capacity equals the total land area in a particular time unit or time interval and it is determined by the spatial boundaries of the East Coast area.

***Total infrastructure land area* (t)/[*t0*]<m2>** = Road infrastructure(t)/[*32500*]<m2> + Rail infrastructure(t)/[*42900*]< m2> + Port infrastructure(t)/[*95900*]< m2> + Remaining land infrastructure with unspecified transport purpose (t)/[*27700*]< m2>

Accordingly, figure 8. depicts a causal loop diagram of described transport congestion (Nguyen, Cook, Ireland, 2017; Bernardino, van der Hoofd, 2013) and infrastructure capacity relations (Ojha et al., 2018) as a whole.

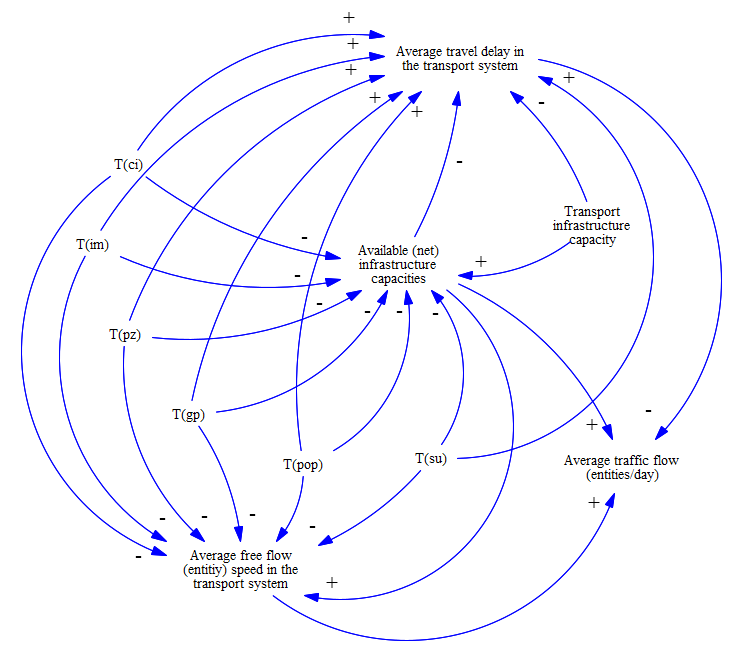


Figure 8. *Causal loop diagram of available infrastructure capacities and transport congestion* (Author's drawing based on Bernardino, van der Hoofd, 2013; Ojha et al., 2018)

In short, on average, the increase of available (net) infrastructure capacity will decrease the hold time in model per system unit and increase average system flow (entities per day) and average entity speed in the transport system and vice versa. By analyzing the available net capacity, two features can be recognized: (1) Permanently loss and security-conditioned infrastructure loss are singularly valued in the conceptual model; (2) Temporary lost capacities are part of ongoing maintenance and similar short-term activities. Consequences of temporarily lost capacities are often estimated in short time intervals using parameters such as average entity speed in the transport system, average free-flow in the transport system, or average traffic flow. These parameters are more practical for discrete event simulations and less for system dynamics but as much valuable for system understanding via conceptual modeling using the system thinking approach. In addition, available (net) road infrastructure incorporates a land area for public (sustainable) transport infrastructure. Public transport utilizes the available road infrastructure without lowering transportation efficiency or effectiveness while decarbonizing urban transport. Therefore, public infrastructure is integrated into the road infrastructure capacities as a unique form of urban mobility that includes a variety of sustainable forms of transportation. In other words, both infrastructures help meet the demand for transport services but use different infrastructure contents (e.g., public – sustainable - infrastructure includes pedestrian infrastructure, bicycle lanes, etc.). Along with the causal loop development, Figure 9 was made by synthesizing the causal loop models shown through this section to provide a holistic view of all variable relations included in the system model development of the East Coast Area.

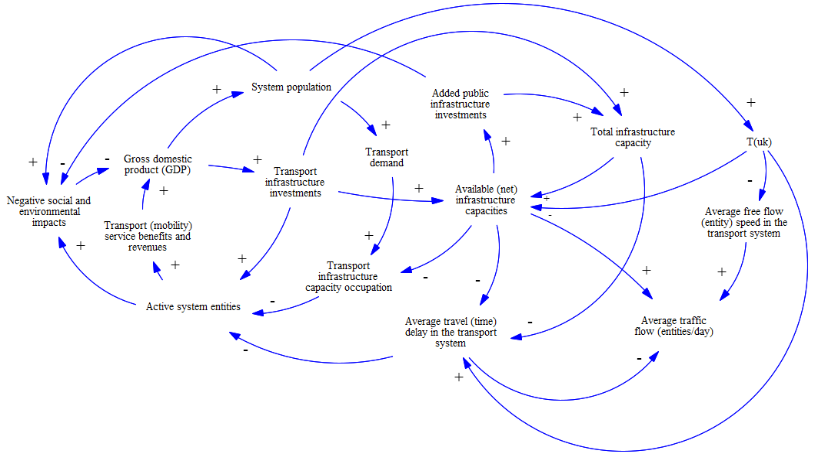
****

Figure 9. *Definite causal loop diagram for transport infrastructure planning* (Author's work)

The final causal loop model represents the conceptual base, a system thinking step required for the dynamic stock-flow quantitative modeling. Still, the suggested causal loop diagram (Figure 9.) does not depict all inner connections between system variables (*system complexity issue*). Additionally, some variables contain a higher number of inputs with the accumulated output (e.g., T(uk)), describe more than one system variable (e.g., infrastructure capacities), or hold different entities into one variable (e.g., system population). Furthermore, outlined variables of a system model do not represent its boundaries since the perception and learning about the transport system grows in time - systems tend to evolve in time under various internal and external influences.

Conclusion and future research directions

The objective of this study was to create a conceptual model using a system thinking approach and preliminary dynamic modeling of an urban mobility performance of the observed area as a relation between transport demand and supply, focusing primarily on infrastructure capacities in operating transport performance. As capacity deficiency of the land transport system is a considerable factor influencing urban development (Yu et al., 2014; Wen, Bai, 2016), this paper examined a variety of studies to enhance transport infrastructure planning using system thinking as an introductory approach to the system dynamic model development. Created causal loop model helps recognize the relationship between transport system variables by determining available infrastructure capacity and long-term mobility potential. Likewise, in order to be with sustainable practices, environmental challenges are included in the model as the development of sustainable alternatives - public infrastructure - to go along with social and ecological issues. Therefore, public infrastructure is a critical infrastructural component of transport systems since it facilitates sustainability in urban development by encouraging transport solutions that positively affect social and environmental issues without compromising mobility performance. Although this study uses a specific research subject as modeling support, the presented approach can be applied in general to support development in other land areas with similar research issues.

Further research for the shown case study requires the creation of a system dynamic model based on the result of this study and preliminary dynamic model guidelines discussed throughout the paper. Additionally, it is required to collect and examine all available data about transport demand in order to test and validate dynamic scenario models for infrastructure performance estimation long-term and find the best possible way to compromise potential data unavailability due to the system complexity of the area, especially those including estimation of the proposed infrastructure projects of the land area.

References

1. Alder, S.D. (2015). *Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development*, ERN: Asia.
2. Angelidou, M., Psaltoglou, A., Komninos, N., Kakderi, C., Tsarchopoulos, P., Panori, A. (2017). Enhancing sustainable urban development through smart city applications. *Journal of Science and Technology Policy Management*.
3. Badada Badassa, B., Sun, B., Qiao, L. (2020). Sustainable Transport Infrastructure and Econimic Returns: A Bibliometric and Visualization Analysis. *Sustainability 2020*, 12(5), pp. 1-24.
4. Banister, D. (1995). *Transport and Urban Development*, London: E & FN Spon.
5. Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, 214(1), pp. 481-518.
6. Benevolo, C., Dameri, R. P., D'Auria, B. (2016). Smart Mobility in Smart City. In: Torre, T., Braccini, A., Spinelli, R. (eds.), *Empovering Organizations. Lecture Notes in information Systems and Organisation*, Springer, Cham, pp. 13-28.
7. Bernardino, J. P. R., van der Hoofd, M. (2013). Parking Policy and Urban Mobility Level of Service – System Dynamics as a Modelling Tool for Decision Making. *European Journal of Transport and Infrastructure Research*, 13(3), pp. 239-258.
8. Boateng, P., Chen, Z., Ogunlana, S., Ikediashi, D. (2012). A system dynamics approach to risks description in megaprojects development. *Organization, technology & management in construction: an international journal*, 4(Special Issue), pp. 593-603.
9. Caponio, G., Massaro, V., Mossa, G., Mummolo, G. (2015). Strategic Energy Planning of Residential Buildings in a Smart City: A System Dynamics Approach. *International Journal of Engineering Business Management*, 7, 20.
10. Cheba, K, Saniuk, S. (2016). Sustainable urban transport – the concept of measurement in the field of city logistics. *Transportation Research Procedia*, 16, pp. 35-45.
11. Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., Pardo, T. A., Scholl, H. J. (2012). Understanding Smart Cities: An Integrative Framework. *45th Hawaii International Conference on System Sciences (2012)*, pp. 2289-2297.
12. City of Split (2005). Prostorni plan uređenja grada Splita. Available at: <https://www.split.hr/ukljuci-se/prostorno-planska-dokumentacija/planovi-na-snazi/ppu-grada-splita> (Accessed: October 02, 2021).
13. Coyle, R. G. (1996). *System Dynamics Modelling: A practical approach*, Chapman & Hall, London.
14. Crescenzi, P., Rodriguez-Pose, A. (2012). Infrastructure and regional groth in the European Union. *Papers in Regional Science*, 91(3), pp. 487-513.
15. Currie, C. S. M., Fowler, J. W., Kotiadis, K., Monks, T., Onggo, B. S., Robertson, D. A., Tako, A. A. (2020). How simulation modelling can help reduce the impact of COVID-19. *Journal of Simulation*, 14(2), pp. 83-97.
16. Ćukušić, M., Jadrić, M., Mijač, T. (2019). Identifying challenges and priorities for developing smart city initiatives and applications. *Croatian Operational Research Review*, 10(1), pp. 117-129.
17. Elburz, Z., Nijkamp, P., Pels, E. (2017). Public infrastructure and regional growth: Lessons from meta-analysis. *Journal of Transport Geography*, 58, pp. 1-8.
18. Elliot, J. A. (2013). *An Introduction to Sustainable Development*, London: Routledge.
19. European Bank for Reconstruction and Development (2020). Master Plan for Kopilica and East Coast. Available at: <https://www.split.hr/clanak/masterplan-studija-za-podrucje-istocne-obale-i-kopilice-integrirani-razvojni-plan> (Accessed: October 02, 2021).
20. Forrester, J. W. (1961). *Industrial Dynamics*, M.I.T. Press, Cambridge.
21. Forrester, J. W. (1994). System Dynamics, Systems Thinking, and Soft OR. *System Dynamics Review*, 10(2), pp. 245-256.
22. Forrester, J. W. (2009). Some basic concepts in system dynamics. *Sloan School of Management, Massachusetts Institute of Technology*, Cambridge, 9.
23. Geng, B., Zheng, X., Fu, M. (2017). Scenario analysis of sustainable intensive land use based on SD model. *Sustainable Cities and Society*, 29, pp. 193-202.
24. Giddings, B., Hopwood, B., O'Brien, G. (2002). Environment, Economy and Society: Fitting Them Together Into Sustainable Development. *Sustainable Development*, 10(4), pp. 187-196.
25. Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., Meijers, E. (2007). Smart Cities – Ranking of European medium-sized cities. *Vienna University of Technology, Centre of Regional Science*.
26. Gil-Garcia, J. R., Pardo, T. A., Nam, T. (2015). What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization. *Information Policy*, 20(1), pp. 61-87.
27. Goh, Y. M., Love, P. E. D. (2012). Methodological application of system dynamics for evaluating traffic safety policy. *Safety science*, 50(7), pp. 1594-1605.
28. Goldman, T., Gorham, R. (2006). Sustainable urban transport: Four innovative directions. *Technology in Society*, 28(1), pp. 261-273.
29. Gonzalez-Feliu, J. (2018). *Sustainable Urban Logistics: Planning and Evaluation*, NJ: John Wiley & Sons, Inc.
30. Griffin, T., Dimanche, F. (2017). Urban tourism: the growing role of VFR and immigration. *Journal of Tourism Futures*.
31. Haghshenas, H., Vaziri, M., Gholamialam, A. (2015). Evaluation of sustainable policy in urban transportation using system dynamics and world cities data: A case study in Isfahan. *Cities*, 45, pp. 104-115.
32. Hall, R. E., Bowerman, B., Braverman, J., Taylor, J., Todosow, H., von Wimmersperg, U. (2000). The Vision of A Smart City. *2nd International Life Extension Technology Workshop*, Paris (FR), Brookhaven National Lab (BNL), Upton, NY (USA).
33. Haraldsson, H. V. (2004). Introduction to system thinking and causal loop diagrams. *Department of chemical engineering, Lund University, Sweden*.
34. Harris, J. M. (2000*). Basic Principles of Sustainable Development*, Working Paper, No. 00-04, Tuffs University, Global Development and Environment Institute, Medford, MA. Available at: <https://notendur.hi.is/bdavids/UAU101/Readings/Harris_2000_Sustainable_development.pdf> (Accessed: June 04, 2021).
35. Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., Williams, P. (2010). Foundations for Smarter Cities. *IBM Journal of Research and Development*, 54(4), pp. 1-16.
36. Hong, J., Chu, Z., Wang, Q. (2011). Transport infrastructure and regional economic growth: evidence from China. *Transportation*, 38(5), pp. 737-752.
37. Hosseinali, F., Alesheikh, A. A., Nourian, F. (2013). Agent-based modeling of urban land-use development, case study: Simulating future scenarios of Qazvin city. *Cities*, 31, pp. 105-113.
38. Institute for Development and International Relations (2019). Predviđanja budućih potreba u sektorima demografije, turizma i ekonomije: Master studija o razvoju Splita ili Urbane aglomeracije. Available at: <https://www.split.hr/DesktopModules/Bring2mind/DMX/API/Entries/Download?language=hr-HR&Command=Core_Download&EntryId=7695&PortalId=0> (Accessed: July 28, 2021).
39. Ismagilova, E., Hughes, L., Dwivedi, Y. K., Raman, K. R. (2019). Smart cities: Advances in research – An information system perspective. *International Journal of Information Management*, 47, pp. 88-100.
40. Jiang, J., Li, J., Xu, H. (2010). System Dynamics Model for Transportation Infrastructure Investment and Cultural Heritage Tourism Development: A Case Study of Xidi and Hongcun Historical Villages. *28th International System Dynamics Conference*, Seoul, Korea, 978.
41. Kekez, I., Jadrić, M., Ćukušić, M. (2021). Demonstration Potential of Simulation Modelling in the Urban Mobility Domain*. The 16th International Symposium on Operations Research in Slovenia*, pp. 23-28.
42. Koglin, T. (2017). Urban mobilities and materialities – a cricital reflection of 'sustainable' urban development. *Applied Mobilities*, 2, pp. 32-49.
43. Lankauskiene, T., Tvaronavičiene, M. (2012). Security and Sustainable Development: Approaches and Dimensions in the Globalization Context. *Journal of Security and Sustainability Issues*, 1(4), pp. 287-297.
44. Lee, J., Arts, J., Vanclay, F., Ward, J. (2020). Examining the Social Qutcomes from Urban Transport Infrastructure: Long-Term Consequences of Spatial Changes and Varied Interests at Multiple Levels. *Sustainability 2020*, 12(15), 5907.
45. Maria, A. (1997). Introduction to modeling and simulation. *Proceedings of the 1997 Winter Simulation Conference*, pp. 7-13.
46. Mäki, U. (2005). Models are experiments, experiments are models. *Journal of Economic Methodology*, 12(2), pp. 303-315.
47. Morchadze, T., Rusadze, N. (2018). Ways to address the challenges in passenger traffic within the urban transport systems. *Transport problems*, 13(3), pp. 65-77.
48. Ninčević Pašalić, I., Ćukušić, M., Jadrić, M. (2020). Smart city research advances in Southeast Europe. *International Journal of Informational Management*, 58, 102127.
49. Ngossaha, J. M., Ngouna, R. H., Archimede, B., Ndjodo, M. F. (2018). A Simulation Model for Risk Assessment in a Smart Mobility Ecosystem Based on the Inoperability Input-Output Theory. *SummerSim '18: Proceedings of the 50th Computer Simulation Conference*.
50. Nguyen, T., Cook, S., Ireland, V. (2017). Application of System Dynamics to Evaluate the Social and Economic Benefits of Infrastructure Projects. *Systems*, 5(2), 29.
51. Noto, G. (2017). Combining system dynamics and perfomance management to support sustainable urban transportation planning. *Journal of Urban and Regional Analysis*, 9(1), pp. 51-71.
52. Ojha, A., Corns, S., Shoberg, T., Qin, R., Long, S. (2018). Modeling and Simulation of Emergent Behavior in Transportation Infrastructure Restoration. In: Mittal, S., Diallo, S., Tolk, A. (eds.) *Emergent Behavior in Complex Systems Engineering: A Modeling Simulation Approach*, John Wiley & Sons, Inc., pp. 349-365.
53. Pawlowski, A. (2009). The Sustainable Development Revolution. *Problems of Sustainable Development*, 4(1), pp. 65-76.
54. Richardson, G. P. (1986). Problems with causal-loop diagrams. *System Dynamics Review*, 2(2), pp. 158-170.
55. Richardson, G. P., Otto, P. (2008). Applications of system dynamics in marketing: Editorial. *Journal of Business Research*, 61, pp. 1099-1101.
56. Richmond, B. (1994). Systems thinking/system dynamics: let's just get on with it. *System Dynamic Review*, 10(2-3), pp. 135-157.
57. Rodrigue, J. P., Comtois, C., Slack, B. (2013). *The Geography of Transport Systems* (Third Edition), New York: Routledge.
58. Rodrigues, A., Bowers, J. (1996). The role of system dynamics in project management. *International Journal of Project Management*, 14(4), pp. 213-220.
59. Saidi, S., Mani, V., Mefteh, H., Shahbaz, M., Akhtar, P. (2020). Dynamic linkages between transport, logistics, foreign direct investment, and economic growth: Empirical evidence from developing countries. *Transportation Research Part A: Policy and Practice*, 141, pp. 277-293.
60. Seidewitz, E. (2003): What models mean. *IEEE Software*, 20(5), pp. 26-32.
61. Skorobogatova, O., Kuzmina-Merlino, I. (2017). Transport Infrastructure Development Perfomance. *Procedia Engineering*, 178, pp. 319-329.
62. Shao, G., Fulong, L., Tang, L (2011). Multidisciplinary perspectives on sustainable development. *International Journal of Sustainable Development & World Ecology*, 18(3), pp. 187-189.
63. Shen, L., Du, L., Yang, X., Du, X., Wang, J., Hao, J. (2018). Sustainable Strategies for Transportation Development in Emerging Cities in China: A Simulation Approach. *Sustainability*, 10(3), 884.
64. Shen, Q., Chen, Q., Tang, B. S., Yeung, S., Hu, Y., Cheung, G. (2009). A system dynamics model for the sustainable land use planning and development. *Habitat International*, 33(1), pp. 15-25.
65. Shepherd, R. B. (2014). A review of system dynamics models applied in transportation. *Transportmetrica B: Transport Dynamics*, 2(2), pp. 83-105.
66. Short, J., Kopp, A. (2005). Transport infrastructure: Investment and planning. Policy and research aspects. *Transport Policy*, 12(4), pp. 360-367.
67. Sterman, J. D. (2000). *Business Dynamics: System thinking and Modeling for a Complex World*, The McGraw-Hill, Boston, USA.
68. Sterman, J. D. (2001). System Dynamics Modeling: Tools for Learning in a Complex World. *California management review*, 43(4), pp. 8-25.
69. Sterman, J. D. (2002). *System Dynamics: System Thinking and Modeling for a Complex World*, Working Paper Series, EDS-WP-2003-01.13, Massachusetts Institute of Technology, USA. Available at: <https://dspace.mit.edu/bitstream/handle/1721.1/102741/esd-wp-2003-01.13.pdf?sequence=1> (Accessed: October 02, 2021).
70. Suryani, E., Hendrawan, R. A., Adipraja, P. F. E., Widodo, B., Rahmawati, U. E., Chou, S. Y. (2022). Dynamic scenario to mitigate carbon emissions of transportation system: A system thinking approach. *Procedia Computer Science*, 197, pp. 635-641.
71. Titos, G., Lyamani, H., Drinovec, L., Olmo, F. J., Močnik, G., Alados-Arboledas, L. (2015). Evaluation of the impact of transportation changes on air quality. *Atmosferic Environment*, 114, pp. 19-31.
72. Tourist Board of the City of Split (2017). Strateški marketinški plan destinacije Split 2017-2022. Available at: <https://visitsplit.com/hr/3136/strateski-marketing-plan> (Accessed: July 28, 2021).
73. United Nations (2019). World Urbanization Prospects: The 2018 Revision. Available at: <https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf> (Accessed: June 19, 2021).
74. UNWTO (n.d.). Glossary of Tourism Terms. Available at: <https://www.unwto.org/glossary-tourism-terms#:~:text=Tourism%20is%20a%20social%2C%20cultural,personal%20or%20business%2Fprofessional%20purposes>. (Accessed: October 02, 2021).
75. Waddel, P. (2002). UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning. *Journal of the American Planning Association*, 68(3), pp. 297-314.
76. Wang, J., Lu, H., Peng, H. (2008). System dynamics model of urban transportation system and its application. *Journal of Transportation Systems engineering and information technology*, 8(3), pp. 83-89.
77. Wang, L., Xue, X., Zhao, Z., Wang, Z. (2018). The Impacts of Transportation Infrastructure on Sustainable Development: Emerging Trends and Challenges. *International Journal of Environmental Research and Public Health*, 15(6), 1172.
78. Wen, L., Bai, L. (2017). System dynamics modeling and policy simulation for urban traffic: a case study in Beijing. *Environmental Modeling & Assessment*, 22(4), pp. 363-378.
79. Wolstenholme, E. F. (1982). System Dynamics in Perspective. *Journal of the Operational Research Society*, 33(6), pp. 547-556.
80. World Commission on Environment and Development (1987). Our common future, Oxford: Oxford University Press. Available at: <https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf> (Accessed: June 04, 2021).
81. Xue, Y., Cheng, L., Wang, K., An, J., Guan, H. (2020). System Dynamics Analysis of the Relationship between Transit Metropolis Construction and Sustainable Development of Urban Transportation – Case Study of Nanchang City, China. *Sustainability*, 12(7), 3028.
82. Xueliang, Z. (2013). Has Transport Infrastructure Promoted Regional conomic Growth? – With an Analysis of the Spatial Spillover Effects of Transport Infrastructure. *Social Sciences in China*, 34(2), pp. 24-47.
83. Yu, B., Zhang, C., Kong, L., Bao, H. L., Wang, W. S., Ke, S., Ning, G. (2014). System dynamics modeling for land transportation system in a port city. *Simulation*, 90(6), pp. 706-716.
84. Zawieska, J., Pieriegud, J. (2018). Smart city as a tool for sustainable mobility and transport decarbonisation. *Transport Policy*, 63, pp. 39-50.
85. Zheng, X. Q., Zhao, L., Xiang, W. N., Li, N., Lv, L. N., Yang, X. (2012). A coupled model for simulating spatio-temporal dynamics of land-use change: A case study in Changqing, Jihan, China. *Landscape and Urban Planning*, 106(1), pp. 51-61.

**Determinants of acceptance and use of the public bike-sharing system**

Introduction

Building an efficient and sustainable transport system is one of the biggest and most important challenges of the urban way of life. Urban centers are considered the main focal points of social and economic activities (Cheba, Saniuk, 2016), and the problem of transport is often manifested in traffic jams and congestion. According to the UN (2020), the total number of people living in cities was approximately 4.4 billion in 2020, and by 2050, 6.7 billion people are expected to live in urban areas. According to Ghate, and Sundar (2013), the constant population growth in limited urban space also causes a significant increase in passenger cars, and thus a major issue of sustainability and environmental impact (Gwilliam et al., 2004). Through the concept of smart cities, various models of urban transport are being developed to facilitate decision-making on the conceptual and logical transport structure and the adaptation of urban infrastructure to new requirements. According to Gonzalez-Feliu (2018), a unique model for sustainable transport is unrealistic for two reasons: the interpretation of the term *sustainable development* varies considerably among researchers, and methods and research approaches also differ, leading to different research results. But it is the concept of sustainable development which focuses on social acceptability, environmental feasibility, and economic viability, that successfully steers urban development toward smart solutions and sustainable development (Goldman and Gorham, 2006).

The dynamic growth of the motor industry is considered the greatest socio-economic transformation of the 20th century. Every family owns at least one personal vehicle, causing a major turnaround in economic activities, the individuals’ daily transportation options, the retail structure, and various ways of accessing education and health needs (Urry, 2008). But, in addition to these great strides in improving living standards, there are different negative consequences of mass use; congestion, collisions, declining air quality, social exclusion, and reduced physical activity, leading to a reduction in general health and an increase in obesity (Docherty et al., 2018). Kampf et al. (2010) state that it is necessary to reduce the use of motor vehicles to a sustainable level, with the expansion of public passenger transport systems as a basic prerequisite for achieving this goal, with the planning of integrated transport systems that open up new transport options. Such an integrated system should take into account the various needs of all components of that system, which may be the needs of the infrastructure, organization, or information system, pedestrians need a crosswalk, cyclists need the infrastructure of bike lines, motor vehicles need a road and a traffic control system, etc.

The research on the smart mobility implementation in Croatia, conducted in 128 cities (Brčić et al., 2018), found that smart concepts, including smart mobility, are increasingly being implemented in cities. The three main components of smart mobility implemented in Croatian cities are ICT technologies (85.2% of cities), smart public transport (65.5 cities), and smart parking (58.6% of cities). Cities where smart mobility development is recognized also have a much higher level of smart urban development than other cities, concluding that smart mobility is a crucial part of smart cities. The notion of smart mobility emerges as a response to accumulated socio-economic problems and is described as a transition of equal reach and importance as motor mobility, where the focus is on making positive changes without compromising transport needs. In other words, without losing the possibility of access to mobility at any time, the transition to green, clean, efficient, and flexible transport is increasingly considered necessary for sustainable development. This smart transition to sustainable transport brings great security benefits and anticipated lower costs to users due to increased resource efficiency of mobility systems (Docherty et al., 2018). Smart mobility is an important component of a smart city, which aims to raise operational efficiency, share information and improve the services quality and living standards (Brčić et al., 2018). Smart mobility contributes to this concept by optimizing travel time, freeing up space, improving economic, environmental, and weather costs, reducing emissions, and reducing traffic congestion. Although smart mobility leads to a cost reduction for users, which can lead to the solution of long-term problems, the transition to a smart mobility system does not happen simultaneously and at the same speed in all areas and regions. Namely, the implementation of smart mobility solutions is predominantly in urban centers, which creates a big difference in the rules of modeling and regulation of urban, semi-urban, and rural areas.

Additionally, problems and their solutions take place at the state level. One of the smart transport models of is also the **bicycle sharing system**, which is a green solution to the problem of urban mobility. Bicycle sharing systems are public bike sharing systems that use the Internet of Things (IoT) technology. IoT refers to the networking of *smart things* that can share information, data, and resources, respond to and act in various situations and environmental changes (Madakam et al., 2015). In this way, citizens are given an alternative, green opportunity to use public transport, with a simple and cheap system of picking up and returning bicycles.

Public bike-sharing systems

By integrating information and communication technology (ICT) into everyday lives, simple activities, such as cycling, fall under the influence of ICT (Ilhan, Fietkiewicz, 2017). Bicycles offer a good alternative for short-distance mobility. According to Kampf et al. (2010), bicycles reach an average speed of 15-25 km/h in urban areas, considered a potential alternative to cars for distances up to 8 km. In addition, the survey says that on average 3/4 of Europeans view the bicycle very positively compared to the car in the city. As a need for an alternative, green type of mobility, public **bicycle sharing systems** are being developed in large urban areas, and these systems are seen as a step towards sustainable urban development. However, such systems require high levels of information flow to be functional - information such as where to pick up the bicycle, how to return it, how to pay, etc. It is necessary for users to start using such systems. Matrai and Toth (2016) cite four generations of public **bicycle sharing systems** (PBSS), with the first system established in Amsterdam in the 1960s. The first generation of PBSS was based on providing free bicycles that users would borrow and return. The first generation did not have organized locations for picking up and returning bicycles and since the service was free, users had no reason to return bicycles in good condition. Eventually, due to vandalism, these systems were soon shut down (Midgley, 2011). In the 1990s the second PBSS generation was launched in Denmark, and it was characterized by custom bicycles and fixed stations; however, it was still free for use. The third generation was established in Copenhagen under the name *Bycyklen* and is considered the first high-scale scheme to be integrated with ICT. In this generation, access with a user card was introduced for the first time at fixed stations that operated with affiliation programs or annual billing. The last fourth generation is the generation of PBSS used today. The main features of this generation are access to mobile devices (via user application and registration system), free use in a certain time frame, providing real-time feedback, use of RFID technology to identify and view bicycle locations, and high-level integration with various systems. Mentioned components were already integrated within the 3rd generation of PBSS. Features that set the fourth generation apart are mobile bicycles pick-up/drop-off stations, solar panels to collect the energy needed to operate the stations, electric bicycles, and mobile applications. Furthermore, Midgley (2011) states that 213 different PBSSs were reported in 2008, almost all of which operated in Europe. Chen et al. (2018) recently introduced the fifth generation referring to systems with bicycles **without stations** and great data management capabilities.

Various favorable factors cause the dynamic growth in the popularity of public bicycle sharing. For example, Munkacsy and Monzon (2017) state that the reason for the rapid growth of the PBS system is its environmental friendliness, its low cost, and its efficiency for short distances, and its efficiency as an intermodal tool. Ilhan and Fietkiewicz (2017) list several PBSS worldwide: YouBike, BiciMAD, Viu BiCiNg, Nextbike, Ofo, Mobike, Forever BIXI, Santander Cycles, The Vélib , Citi Bike, O'Bike and Q Bike.

The case of Nextbike in the city of Split

Nextbike smart mobility solution has been implemented in more than 300 cities worldwide, including Croatia (Vlastos et al., 2014). While there are other PBSS in European countries (such as *EasyBike, Bixi, Call a Bike, Bicimad*), the *Nextbike* project is the most famous and commonly used PBSS in Europe. Matrai and Toth (2020) state Nextbike as a classic example of an organization that operates as both owner and provider; in other words, Nextbike provides and maintains bicycles and manages the entire system. A significant advantage of this prevalence is the ability to log in to any city where Nextbike is implemented. Nextbike is considered the largest PBSS in the region. The project has been implemented in about 20 Croatian cities, and in 2019 this project was introduced in the city of Split. Currently, there are 80.000 users registered in Croatia, of which more than 24.000 are registered in Split (Nextbike, Milanović, 2021).

Furthermore, there are currently about 300 bicycles in Split as part of the Nextbike project, of which 182 electric bicycles are deployed at 41 stations. An interview conducted with Nextbike Split staff revealed that the plan is to expand the number of bicycles and the number of stations and racks to bring even more citizens closer to using this form of transport. 80% of the total users are locals who have recognized cycling as a great green alternative to public transportation. It has previously been stated that cyclists reach an average speed of 15-25km/h, which is considered a good alternative solution for passenger cars for 8km (Kampf et al., 2010). Considering that the use is free for the first 30 minutes, it is more than enough for public transport since the area of Split covers about 80 km2. Another significant advantage of PBSS over using private transportation is that it solves the problem of finding a parking space, which is especially prevalent during the summer season.

The bicycle rental **has three steps**. The first step is user subscription, which begins with registration via a mobile application, customer support center, and set up Nextbike stations or website. Upon registration, the user enters a plan for using the system, and once the account is created, the user can use Nextbike systems worldwide. Payment can be made by credit/debit card, SMS message, or bank transfer. Registration cannot be done without submitting the photo of ID used for identity confirmation, protection against vandalism, and confirmation that the user is old enough to use the system. After the registration process is finished, the user receives a confirmation e-mail. The second step is to rent a bicycle, and it can be done in several ways:

1. the first way is to use a mobile application and it assumes entering the bicycle number and the security pin;
2. another way is to use the station, then user needs to select the rental on the touch screen, enter the mobile phone number and registration pin, as well as the bicycle number;
3. the third way is to scan the bike’s QR code which automatically registers the rent in the system;
4. it is possible to rent a bike by calling the user number.

After choosing one of the rental methods, the user takes the bicycle and starts riding. At the end of the ride the bicycle needs to be returned to the **station**, which is done by pushing the bicycle into the lock which locks automatically. If the bicycle is returned correctly, the station emits an acknowledgment sound signal, and the status that the bicycle has been returned is displayed on the mobile application. It is also possible to temporarily park the bicycle using the functions of the mobile applications *Park* and *Continue renting*. In case all the racks are occupied, the bicycle must be locked manually with a mechanical padlock for the stand on the station. The additional option of using Nextbike systems is creating the Nextbike card, which simplifies the entire process of renting a bicycle (the cost of a card is 20kn). The Nextbike system also provides a smart fault tracking solution that deactivates bicycles after a report or automatic fault detection so they cannot be rented.

All these aspects of the smart solution of the Nextbike system are supported by a network of applied technologies that make the whole system work. For example, setting up the station is meaningless without networking and setting security measures, bicycles without tracking methods cannot be numbered and tracked, and parking bicycles would not be possible without the supporting technology of bicycle registration. Administration of the entire Nextbike system takes place via the Nextbike cloud Office software. It is a complete CRM system for administering user processes and, at the same time, makes a remote diagnostic tool for efficient management of bicycle fleets and stations.

**Map locations of** stations in Split are shown in Figure 1.

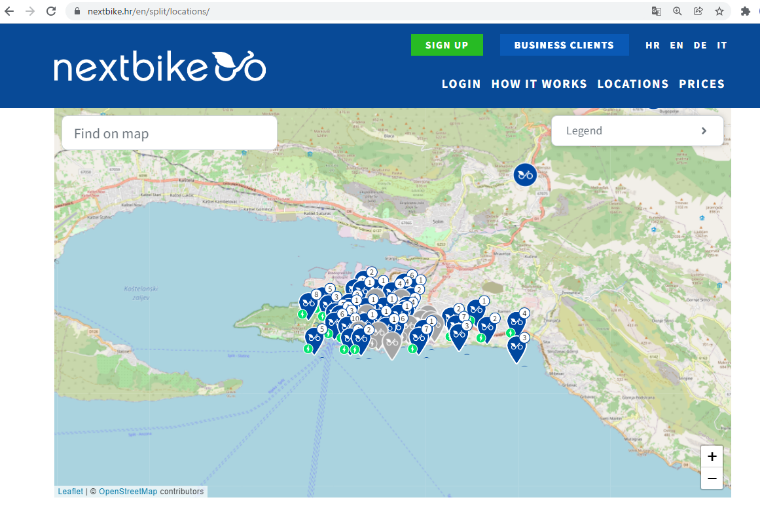


Figure 1. Nextbike map with the locations of all stations in the city of Split

All Nextbike stations in Split have a SIM card and some stations are connected by an optical network. The SIM card (subscriber identity module) is considered a method of specific security cryptography of device security and this cryptographed algorithm is extremely difficult to hack (Pang et al., 2013). A SIM card is a module that contains and encrypts information when sent to the main system. When all information from both sender and receiver is confirmed, the message can be decrypted. In this way, communication between the terminal and the main system occurs in a secure encrypted way. A solar panel is connected to each terminal which is sufficient for the self-sustaining power supply of the station. The terminals are equipped with a touch screen and an RFID reader.

However, in an interview with the staff of Nextbike Split, it was stated that an optical network connects some locations. In addition, there are cameras at all locations that are connected to the Split parking control center (via optical networking). According to Ji and Wang (2016), optical networking is a key contributor to IoT networks and communications, emphasizing fiber optic technologies.

The IoT technology is also integrated into each bicycle, from which several types of bicycles differ: classic bicycles, classic eco-bicycles, smart bicycles, and e-smart bicycles (Nextbike, 2016). The classic bicycle contains an adapter with an RFID chip for docking and communication with smart stations. The station recognizes bike’s chip using the RFID radio waves and automatically registers bicycles pick-up/return. It then passes this information to the system, and the user can view the bicycle status in the Nextbike application. The redesign of the classic bicycle into a classic eco- bicycle refers to replacing ecologically non-renewable bicycle parts with eco-renewable ones. The smart bicycles are based on the classic bicycle model combined with smart electric computer components and unique locking technology. The bicycle has an integrated electro-mechanical locking system and the electric computer has integrated GPS and GSM communication modules for monitoring the geolocation of the bicycle. Additionally, NFC reader provides internal data storage and the computer controls the locking mechanisms of the bicycle. The e-smart bicycles are electric bicycles made based on a smart bicycles containing a rechargeable motor, which is charged on the stations.

Another smart characteristic of the Nextbike system is the mobile application. According to Nextbike, in some cities, more than 80% of bookings are made via the mobile application thanks to the integration of smart technologies. Easy access to bicycles is provided by scanning the QR code on bicycles, or by NFC scanning. In this way, it is not necessary to enter additional data (PIN, username, etc.). The application provides additional features such as access to maps with the stations' locations, location of available bicycles, driving history, account information, and the possibility of reporting bicycles damage.

Conceptual Grounding and Hypotheses Development

Unified Theory of Acceptance and Use of Technology (UTAUT) is one of the most popular theories applied in various research to examine the *behavioral intention* and real *use behavior* of specific technology users. Venkatesh et al. (2003) presented the UTAUT model as a result of a combination of 8 different theories: Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Motivational Model (MM), Theory of planned behavior (TPB), and Combined Theory of Planned Behavior/Technology Acceptance Model (C-TPB-TAM), Model of PC Utilization (MPCU), Innovation Diffusion Theory (IDT), and Social Cognitive Theory (SCT). TAM stands out as the model closest to UTAUT, since both models suggest that technology use is influenced by behavioral intention to use technology (Shachak et al., 2019). UTAUT model has been extended into the UTAUT2 model with additional predictors: hedonic motivation, price value, and habit.

This study empirically tested a model to predict the *factors affecting users’ behavioral intentions to use the PBSS in the city of Split*. Along with *behavioral intention* and *use behavior*, variables *performance expectancy*, *effort expectancy*, *social influence*, and *facilitating conditions* from UTAUT were included in the research model. Furthermore, the *price value* variable was taken from the UTAUT2, and the model was additionally extended with *perceived risk*, *environmental awareness*, *and physical activity*.

*Performance expectancy* (Dwivedi et al., 2011) is defined as the level to which individuals believe that the use of new technology will improve their performance. Users will be more motivated to use new technologies if they believe that implementing this technology will positively impact their everyday lives. As the Nextbike Split provides an answer to solving the problem of congestion, emission, and parking, the assumption is that *performance expectancy will positively affect the behavioral intention to use the Nextbike system* (H1).

*Effort expectancy* refers to the level of simplicity tied with the use of the system. Regardless of how good the system is as a solution to the problem, its applicability completely fails if users cannot learn to use it. According to Alalwan et al. (2017), an individual's intention to use a system is predicted not only by the positive features of the system but also by the level of ease of use, in other words, as the effort required to get used to and learn a new system rises, the users are less likely actually to use the system. The hypothesis is that the *effort expectancy will positively affect the behavioral intention to use the Nextbike system* (H2).

*Social influence* refers to an individual’s perception of others’ opinions about whether or not they should use new technology (Venkatesh et al., 2003). Social influence can come from various sources, such as family, reference groups, friends, colleagues, etc. (Alawan et al., 2017). Therefore, if the social impact of an individual's environment on the new technology is negative, that individual's opinion will be tilted to the negative side. On the other hand, if the social influence is positive, it is more likely that *social impact will positively affect behavioral intention to use the Nextbike system* (H3).

According to Venkatesh et al. (2003), facilitating conditions refer to how an individual believes that an organizational and technical infrastructure exists to support the use of the system. Therefore, the assumption is that the *facilitating conditions will positively affect the use (behavior) of the Nextbike system* (H4).

*Price value* (Dwivedi et al., 2011) refers to the user's perceived value for money. If the user perceives that the value of using the technology is favorable, i.e., that the use is profitable, he is more likely to use it. In case the user thinks that the use of the service is more expensive than it should be, the aversion to the use of technology will increase. Therefore, the *price value will positively affect behavioral intention to use the Nextbike system* (H5).

*Perceived risk* is related to users that sense any likely losses that could arise as a result of the uncertainties of utilizing technology, while the anticipated losses may involve any unfavorable results to end-users like financial losses, the violation of privacy, psychological concern, waiting time, etc. (Kofi Penney et al., 2021). It is hypothesized that the *perceived risk will positively affect behavioral intention to use the Nextbike system* (H6).

*Environmental awareness* refers to the environmental effects of using a public bicycle sharing system on the environment, as opposed to alternative opportunities for public and private mobility, so the assumption is that *environmental awareness will positively affect behavioral intention to use the Nextbike system* (H7).

Furthermore, cycling also requires some level of physical activity, which also directly impacts health. For that reason, it is assumed that *physical activity will positively affect behavioral intention to use the Nextbike system* (H8).

While performance expectancy, effort expectancy, social influence, price value, perceived risk, environmental awareness, and physical activity are the main predictors of behavioral *intention to use* technology, variables behavioral intention to use and facilitating conditions affect the *use* behavior. *Behavioral intention (that refers to the user's overall attitude towards technology) will positively affect the use behavior* (H9).

Data and Methods

## Research instrument

The main constructs of the questionnaire were: *performance expectancy*, *effort expectancy*, *social influence*, *facilitating conditions*, *price value*, *perceived risk*, *environmental awareness*, *physical activity*, and *behavioral intention*. The questionnaire consists of 30 items measured by the Likert scale from 1 (*I completely disagree*) to 7 (*I completely agree*). A total of 239 questionnaires were collected, of which 35 respondents partially completed the questionnaire and were rejected from further analysis. Therefore, the total number of questionnaires in the analysis was 204. The questionnaire was created using the LimeSurvey tool and conducted online. Responses to the questionnaire were collected over two months and were collected in July and August by sending questionnaires directly to respondents and with the help of Nextbike staff.

## Participant demographics

Out of a total of 204 respondents, 94 (46%) are aged 25-34 years, 56 respondents (27%) are aged 35-44 years, and 43 (21%) are aged 18-24 years. Of the other age groups, 9 respondents (4%) answered that they belong to 45-60 years, while one person (0.49%) is in the age group of 60+ years. The majority of respondents are male (67%), compared to 33% female. A total of 110 (53%) respondents owned a car. On the other hand, owning a bicycle is much more polarizing, whereas 44 (22%) respondents own a bicycle. Usage experience refers to the user's frequency of use of the Nextbike system. Of the 204 respondents, 102 (50%) answered that they never use the Nextbike system, while 50% used the system at least once. Of these, 38 (19%) use the system once a month, 30 (15%) respondents use the system once a week, 27 (13%) respondents use the system several times a week, and 7 (3%) respondents use Nextbike daily.

## Data analysis methods

For defining the variable structure of the proposed research model, factor analysis was applied (Hair et al., 2010). Only items whose difference in factor cross-loadings was 0.2 or greater and the factor loading was at least 0.4 were kept. The minimal sample size has been achieved (200+), and the ratio of participants and variables is satisfactory (Hair et al., 2010). To check internal consistency, Cronbach's alpha coefficient was calculated (Cronbach, 1951). In addition, regression analysis was used to determine the relative contribution (independent relationship) for each explanatory variable by controlling for the effects of other explanatory variables.

Results

Although values for skewness and kurtosis between -2 and +2 are considered acceptable to prove a normal distribution (George and Mallery, 2010), other lower acceptable ranges for skewness and kurtosis below +1.5 and above -1.5 (Tabachnick and Fidell, 2013) have been advocated to consider the distributions normal. The mean does not vary significantly and ranges from 3.33 to 5.08 for the items on a scale of 1 to 7. Only one item (*usage behavior*) has a mean of 2.01, but this item is measured on a scale of 1 to 5. All distributions are normal, i.e., they meet the criterion of skewness or kurtosis below +1.5 and above -1.5. Descriptive statistics are calculated and presented in Table 1.

Table 1. Descriptive statistics

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Construct | Item | N | Min | Max | Mean | Std. Dev. | Skewness | Courtesy |
| Performance Expectancy  UTAUT | PE1 | 204 | 1 | 7 | 4,07 | 1,805 | -,149 | -1,089 |
| PE2 | 204 | 1 | 7 | 4,09 | 1,976 | -,162 | -1,261 |
| PE3 | 204 | 1 | 7 | 4,26 | 1,965 | -,190 | -1,167 |
| PE4 | 204 | 1 | 7 | 4,18 | 1,945 | -,100 | -1,132 |
| Effort Expectancy  UTAUT | EE1 | 204 | 1 | 7 | 4,61 | 1,774 | -,418 | -,909 |
| EE2 | 204 | 1 | 7 | 4,62 | 1,809 | -,399 | -,898 |
| EE3 | 204 | 1 | 7 | 4,68 | 1,841 | -,369 | -,917 |
| EE4 | 204 | 1 | 7 | 4,67 | 1,821 | -,413 | -,803 |
| Social Influence  UTAUT | SI1 | 204 | 1 | 7 | 4,23 | 1,354 | -,150 | -,025 |
| SI2 | 204 | 1 | 7 | 4,28 | 1,491 | -,075 | -,333 |
| SI3 | 204 | 1 | 7 | 4,24 | 1,511 | -,025 | -,325 |
| Facilitating Conditions  UTAUT | FC1 | 204 | 1 | 6 | 3,77 | 1,495 | -,234 | -,834 |
| FC2 | 204 | 1 | 7 | 4,69 | 1,702 | -,390 | -,793 |
| FC3 | 204 | 1 | 7 | 4,56 | 1,779 | -,233 | -1,106 |
| FC4 | 204 | 1 | 7 | 4,71 | 1,681 | -,170 | -1,000 |
| Price Value  UTAUT2 | PV1 | 204 | 1 | 7 | 4,88 | 1,534 | -,519 | -,484 |
| PV2 | 204 | 1 | 7 | 5,03 | 1,567 | -,631 | -,434 |
| PV3 | 204 | 1 | 7 | 5,03 | 1,580 | -,564 | -,563 |
| Perceived Risk | PR1 | 204 | 1 | 7 | 3,42 | 1,286 | , 264 | -,269 |
| PR2 | 204 | 1 | 7 | 3,51 | 1,218 | -,130 | ,148 |
| PR3 | 204 | 1 | 7 | 3,33 | 1,423 | , 057 | -,414 |
| Environmental awareness | EA1 | 204 | 1 | 6 | 4,97 | , 931 | -1,015 | 1,499 |
| EA2 | 204 | 1 | 6 | 4,99 | , 893 | -,886 | 1,544 |
| Physical activity | PA1 | 204 | 1 | 7 | 5,08 | 1,389 | -,396 | -,504 |
| PA2 | 204 | 1 | 7 | 4,76 | 1,529 | -,248 | -,759 |
| PA3 | 204 | 1 | 7 | 4,70 | 1,602 | -,235 | -,777 |
| Behavioral Intention  UTAUT | BI1 | 204 | 1 | 7 | 4,02 | 1,940 | -,085 | -1,341 |
| BI2 | 204 | 1 | 7 | 3,37 | 2,065 | , 359 | -1,256 |
| BI3 | 204 | 1 | 7 | 4,48 | 1,946 | -,292 | -1,196 |
| BI4 | 204 | 1 | 7 | 4,52 | 1,903 | -,307 | -1,145 |
| Use behavior (UTAUT) | USE | 204 | 1 | 5 | 2,01 | 1,222 | ,872 | -,512 |
| Valid N (listwise) | | 204 |  |  |  |  |  |  |

Principal component analysis was performed with the 30 variables. Since the number of respondents was N = 204, the ratio of the number of respondents and variables met the criterion of 5:1 (Hair et al., 2010). The KMO test (0.917) confirms the adequacy of the sample, the tested model fits the data, and Bartlett's test for sphericity is statistically significant. The factor structure was set at 8 components, and only items of those scales were analyzed whose influence on behavioral intention, and use behavior is assumed in the hypothesized model. Factor analysis was performed without behavioral intention (items are not adequately projected on the corresponding factor) and without behavior (only one was item analysed). Results are shown in Table 2.

Table 2. Total variance explained for the factor structure

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | | Rotation Sums of Squared Loadings | | |
| Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | | % of Variance | Cumulative % |
| 1 | 13,522 | 52,007 | 52,007 | 13,522 | 52,007 | 52,007 | 4,176 | | 16,063 | 16,063 |
| 2 | 2,478 | 9,531 | 61,538 | 2,478 | 9,531 | 61,538 | 3,076 | | 11,831 | 27,894 |
| 3 | 1,871 | 7,195 | 68,733 | 1,871 | 7,195 | 68,733 | 3,075 | | 11,828 | 39,722 |
| 4 | 1,380 | 5,307 | 74,040 | 1,380 | 5,307 | 74,040 | 3,073 | | 11,819 | 51,542 |
| 5 | 1,120 | 4,308 | 78,348 | 1,120 | 4,308 | 78,348 | 2,812 | | 10,817 | 62,358 |
| 6 | 1,091 | 4,197 | 82,545 | 1,091 | 4,197 | 82,545 | 2,597 | | 9,988 | 72,346 |
| 7 | ,950 | 3,655 | 86,200 | ,950 | 3,655 | 86,200 | 2,423 | | 9,321 | 81,667 |
| 8 | ,784 | 3,015 | 89,215 | ,784 | 3,015 | 89,215 | 1,962 | | 7,547 | 89,215 |
| Extraction Method: Principal Component Analysis. | | | | | | | | | | |

Table 3. Rotated Component Matrix

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Component | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| PE3 Using a bikeshare system helps me to complete tasks faster. | ,847 |  |  |  |  |  |  |  |
| PE2 Using the bikeshare system increases the chances of achieving the tasks that are important to me. | ,839 |  |  |  |  |  |  |  |
| PE4 Using a bikeshare system raises my productivity. | ,834 |  |  |  |  |  |  |  |
| PE1 I find the bikeshare system useful in my daily life. | ,764 |  |  |  |  |  |  |  |
| SI2 People who influence my behavior think that I should use a bikeshare system. |  | ,865 |  |  |  |  |  |  |
| SI3 People whose opinions I value prefer to use the bikeshare system. |  | ,859 |  |  |  |  |  |  |
| SI1 People who matter to me think I should use a bikeshare system. |  | ,815 |  |  |  |  |  |  |
| FC1 I have the resources needed to use the bikeshare system. |  |  | ,830 |  |  |  |  |  |
| FC2 I have the knowledge needed to use the bikeshare system. |  |  | ,756 |  |  |  |  |  |
| FC4 I can get help from others when I have difficulty using the bikeshare system. |  |  | ,675 |  |  |  |  |  |
| FC3 The Bikeshare system is compatible with other technologies I use. |  |  | ,659 |  |  |  |  |  |
| PV1 The Bikeshare system has a reasonable price. |  |  |  | ,865 |  |  |  |  |
| PV2 The Bikeshare system provides good value for money. |  |  |  | ,842 |  |  |  |  |
| PV3 At the current price, the Bikeshare system provides good value. |  |  |  | ,830 |  |  |  |  |
| EE4 It's easy for me to become proficient in using a bikeshare system.] Expected effort: |  |  |  |  | ,730 |  |  |  |
| EE2 My interaction with the bikeshare system is clear and understandable. | ,412 |  |  |  | ,715 |  |  |  |
| EE3 I find the bikeshare system easy to use. |  |  |  |  | ,691 |  |  |  |
| EE1 It's easy for me to learn to use the bikeshare systemExpected effort: |  |  |  |  | ,687 |  |  |  |
| PA3 I want to use a bikeshare system because of the physical activity it provides me. |  |  |  |  |  | ,824 |  |  |
| PA2 I find that the bikeshare system provides me with adequate physical activity. |  |  |  |  |  | ,823 |  |  |
| PA1 Using a bikeshare system is good for my health. |  |  |  |  |  | ,680 |  |  |
| PR2 Using a bikeshare system puts me at risk. |  |  |  |  |  |  | ,928 |  |
| PR1 I find that using the bikeshare system threatens my privacy. |  |  |  |  |  |  | ,913 |  |
| PR3 Using a bikeshare system will not fit well into my image. |  |  |  |  |  |  | ,774 |  |
| EA2 I believe that the bikeshare transport system is more sustainable than other transport systems. |  |  |  |  |  |  |  | ,878 |
| EA1 By using the bikeshare system I have a positive impact on the environment. |  |  |  |  |  |  |  | ,875 |
| Extraction Method: Principal Component Analysis.  Rotation Method: Varimax with Kaiser Normalization. | | | | | | | | |
| a. Rotation converged in 6 iterations. | | | | | | | | |

Calculated Cronbach alpha of extracted factors were: PE=0.965, EE=0.972, SI=0.950, FC=0.937, PV=0.979, PR=0.851, EA=0.877, PA=0.897, Initial construct BI=0.950. According to the previously presented hypothetical model, the analysis is divided into 2 regression models: *the first model measures the impact of observed predictors on behavioral intention*, while the second refers to mea*suring the impact of behavioral intention and facilitating conditions on use behavior*. The model tested if the extracted factors can significantly predict the behavioral intention. The results including the level of statistical significance, the standardized Beta coefficient, R, and R-squared, are presented in Table 4. The R-value of 0.903 is quite high, where the minimum value for further analysis is 0.4 (Jain and Chetty, 2019). The R2 value refers to the total variation of the dependent variable that can be explained by the independent variables. The minimum required variance value should be 0.5, and the R2 value of the model satisfies this condition.

Furthermore, an ANOVA test was performed, which shows whether the significance of the model is high enough to estimate the model's output. The significance of the model should be less than 0.05 for the variable to be considered significant. In this model, the significance level is <0.01, which means that the model is significant.

Table 4. Enter linear regression for dependent variable behavioral intention.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coefficients** | | | | | | |
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| B | Std. Error | Beta |
| Enter linear regression  R=0,903  R Square=0,815 | (Constant) | -1,657 | ,409 |  | -4,049 | ,000 |
| PE | ,269 | ,049 | ,269 | 5,444 | ,000 |
| EE | ,191 | ,059 | ,181 | 3,221 | ,001 |
| SI | ,276 | ,055 | ,209 | 5,019 | ,000 |
| PV | ,181 | ,053 | ,151 | 3,426 | ,001 |
| PR | -,097 | ,051 | -,061 | -1,880 | ,062 |
| EA | ,067 | ,078 | ,032 | ,869 | ,386 |
| PA | ,345 | ,057 | ,259 | 6,073 | ,000 |
| a. Dependent Variable: BI | | | | | | |

It is evident that the variables PR (perceived risk) and EA (environmental awareness) have a significance higher than 0.05 (values 0.062 and 0.386). Therefore, it was concluded that the PR and EA variables *do not significantly impact behavioral intention*. Using the Stepwise method of entering data into the regression model, variables that were not statistically significant were omitted. The previously mentioned F value, which should be between 0.5 and 1, was used as a criterion for data entry. By adding independent variables to the model, the values of R and R 2 increase. In other words, model 5 shown in Table 4, which includes all statistically significant constructs, best describes the variation of the dependent variable BI.

Table 5. Stepwise linear regression in 5th step for dependent variable behavioral intention.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coefficients** | | | | | | |
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| B | Std. Error | Beta |
| Stepwise linear regression  R=0,900  R Square=0,811 | (Constant) | -1,822 | ,242 |  | -7,515 | ,000 |
| EE | ,204 | ,059 | ,194 | 3,462 | ,001 |
| PA | ,350 | ,054 | ,263 | 6,446 | ,000 |
| PE | ,270 | ,050 | ,270 | 5,435 | ,000 |
| SI | ,263 | ,055 | ,199 | 4,781 | ,000 |
| PV | ,207 | ,051 | ,173 | 4,054 | ,000 |
| a. Dependent Variable: BI | | | | | | |

It can be concluded that five constructs (effort expectancy, physical activity, performance expectancy, social influence, price value) *have a significant impact on behavioral intention*. However, *variables perceived risk and environmental awareness are not statistically significant predictors of bihevioral intention*. Since the results of stepwise linear regression coincide with the results of enter linear regression, the interpretation of only the enter linear regression model will be presented below.

The performance expectancy has a significant and positive impact on the behavioral intention to use the Nextbike system confirming hypothesis H1 (significance level <.001 and a standardized beta coefficient of 0.269). The effort expectancy with a significance level of 0.001 and a standardized beta coefficient of 0.181 positively affects the behavioral intention to use the Nextbike system by users, which confirms hypothesis H2. The social influence has a significance level of <.001 and a beta coefficient of 0.209. Therefore, it also has a statistically significant and positive impact on the intended use, as evidenced by the H3 hypothesis. The price value with a significance level of 0.001 and a standardized beta coefficient of 0.151 has a significant and positive impact on the intended use of the Nextbike system, which confirms hypothesis H5. A construct that does not reach the required level of significance is a perceived risk which indicates a predominantly negative user perception. Although the significance of perceived risk is 0.062 and is not considered a statistically significant influence on the purpose of the behaviour its impact is negative with a standardized beta coefficient of -0.061, therefore, hypothesis H6 cannot be accepted. Another statistically negligible construct is environmental awareness. The level of significance of this construct is 0.386, and the standardized beta coefficient is 0.032. In both cases, the structure of the answers to the questions is extremely polarizing, with over 90% of respondents expressing a level of agreement with the claims. Therefore, environmental awareness has an extremely small impact on the intended use of users, and hypothesis H7 is also rejected. Finally, physical activity also positively affects behavioral intention with a significance level of <.001 and a standardized beta coefficient of 0.259, confirming the H8 hypothesis.

The second model tests the effects of the facilitating conditions and behavioral intention on use behavior. Usage was examined by asking the question, *How often do you use the Nextbike system*.

Table 6. Stepwise linear regression in 5th step for dependent variable behavioral intention

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coefficients a** | | | | | | |
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| B | Std. Error | Beta |
| Enter linear regression  R=0.702  R Square=0.493 | (Constant) | ,000 | ,188 |  | -,001 | ,999 |
| FC | ,055 | ,062 | ,069 | ,886 | ,377 |
| BI | ,432 | ,052 | ,648 | 8,297 | ,000 |
| a. Dependent Variable: How often do you use the next-bike system? | | | | | | |

The R-value is 0.702, which satisfies the condition that the value is greater than 0.4. However, the R2 value does not meet the condition that the value is greater than 0.5. This means that the model is not very effective in predicting the relationships between independent and dependent variables, although a value of 0.493 is relatively close to a satisfactory level. The facilitating conditions do not have a significant impact on the use of technology, with a beta coefficient of 0.069 and a significance level of 0.377, thus rejecting hypothesis H4. Therefore, the facilitating conditions construct has been dropped from the model, and behavioral intention remains the only factor that has a significant impact on the use of technology, which confirms hypothesis H9.

Conclusion

Research results show a *significant and positive relationship between effort expectancy, physical activity, performance expectancy, social influence, and price value with behavioral intention to use Nextbike system.* Also, *the relationship between behavioral intention to use and actual use of Nextbike system is significant and positive*. Since its inception in the 1960s, PBSSs have been transformed into highly standardized and technologically equipped systems that compete with standard public transportation systems. The Nextbike project was implemented in Split in 2019; today has more than 24, 000 registered users and includes 300 bicycles deployed at 41 stations. Although cycling in the city of Split is quite underdeveloped and new, this *project has been successfully implemented and accepted by a large number of residents*. Using data transfer technologies attached to the concept of the IoT, Nextbike Split belongs to the category of smart and sustainable solutions. Furthermore, a *sustainable concept should have a high impact on the formulation of urban development policies and strategies that promote constant economic and social progress*. This research certainly contributes to *raising awareness and identifying the dominant factors influencing the intention to use this type of green and sustainable transport*.

Acknowledgments

This research was supported by the Croatian Science Foundation [grant number UIP-2017-05-7625].

References

1. Alalwan A. A., Dwivedi, Y. K., Rana, N. P. (2017). Factors influencing adoption of mobile banking by Jordanian bank customers: Extending UTAUT2 with trust. *International Journal of Information Management*, Volume 37, Issue 3. [doi: 10.1016/j.ijinfomgt.2017.01.002](https://doi.org/10.1016/j.ijinfomgt.2017.01.002).
2. Brčić, D., Slavulj, M., Šojat, D., Jurak, J. (2018). The role of smart mobility in smart cities. In *Fifth International Conference on Road and Rail Infrastructure (CETRA 2018)*. Available at: <https://www.bib.irb.hr/946193/download/946193.CETRA2018_1601-1606.pdf>
3. Cheba, K., Saniuk, S. (2016). Sustainable urban transport – the concept of measurement in the field of city logistics. *Transportation Research Proceedings*, 16, pp. 35-45. [doi: 10.1016/j.trpro.2016.11.005](https://doi.org/10.1016/j.trpro.2016.11.005).
4. Chen F., Turon K., Klos M., Czechm P., Pamula W., Sierpinski G. (2018). Fifth-generation bike-sharing systems: examples from Poland and China. *Scientific journal of Silesian university of technology*. [doi: 10.20858/sjsutst.2018.99.1](https://doi.org/10.20858/sjsutst.2018.99.1).
5. Docherty I., Marsden G., Anable J., (2018). The governance of smart mobility. Transportation Research Part A: *Policy and Practice*, Vol. 115, pp. 114-125. doi: [10.1016/j.tra.2017.09.012](https://doi.org/10.1016/j.tra.2017.09.012).
6. George, D., Mallery, M. (2010). SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 update (10 ed.). Boston: Pearson
7. Goldman, T., Gorham, R. (2006). Sustainable urban transport: Four innovative directions. *Technology in Society*, 28 (1-2), pp. 261-273. doi:[10.1016/j.techsoc.2005.10.007](https://doi.org/10.1016/j.techsoc.2005.10.007).
8. Gonzalez-Feliu, J. (2018). *Sustainable Urban Logistics: Planning and Evaluation*, NJ: John Wiley & Sons, Inc. Available at: <https://onlinelibrary.wiley.com/doi/book/10.1002/9781119421948>.
9. Gwilliam, K. M., Kojima, M., Johnson, T. (2004). Reducing air pollution from urban transport. Washington, DC: World Bank. Available at:<https://esmap.org/sites/default/files/esmap-files/urban%20pollution%20entire%20report.pdf>
10. Ilhan A., Fietkiewicz K. (2017). Think Green- Bike! The Bicycle Sharing System in the Smart City of Barcelona. Department of Information Science, Heinrich Heine University. pp. 309-323. Available at: [https://www.researchgate.net/publication/328799708\_A\_Bibliometric\_Analysis\_of\_Studies\_ on\_Medical\_Radiation\_Workers\_Active\_Authors\_Hot\_Topics\_and\_Malaysian\_Works\_in\_t he\_Research\_Landscape](https://www.researchgate.net/publication/328799708_A_Bibliometric_Analysis_of_Studies_on_Medical_Radiation_Workers_Active_Authors_Hot_Topics_and_Malaysian_Works_in_the_Research_Landscape)
11. Jain, R., Chetty, P. (2019). How to interpret the results of the linear regression test in SPSS? . [online] Project Guru. Available at: [https://www.projectguru.in/interpret-results- linear-regression-test-spss/](https://www.projectguru.in/interpret-results-linear-regression-test-spss/) (Accessed September 01, 2021).
12. Hair J. F., Black W. C., Babin B. J., Anderson R. E. (2010). *Multivariate Data Analysis*, Pearson Prentice Hall.
13. Ji P. N., Wang T. (2016). Internet of things with optical connectivity, networking, and beyond. *The 21st OptoElectronics and Communications Conference (OECC)* was held jointly with the 2016 International Conference on Photonics in Switching (PS). Available at: <https://ieeexplore.ieee.org/abstract/document/7718328>
14. Kampf R., Gašparík J., Kudláčková N. (2012). Application of different forms of transport in relation to the process of transport user value creation. 40(2). Available at: <https://pp.bme.hu/tr/article/view/7006>
15. Kofi Penney, E., Agyei, J., Kofi Boadi, E., Abrokwah, E., Ofori-Boafo, R. (2021). Understanding Factors That Influence Consumer Intention to Use Mobile Money Services: An Application of UTAUT2 With Perceived Risk and Trust. *SAGE Open*, 11(3), 2021. doi: 10.1177/21582440211023188.
16. Madakam, S., Lake, V., Lake, V., Lake, V. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications*, 3 (05), 164. doi: [10.4236/jcc.2015.35021](http://dx.doi.org/10.4236/jcc.2015.35021).
17. Matrai T., Toth J., (2020). Cluster Analysis of Public Bike Sharing Systems for Categorization. *MDPI*. Available at: <https://www.mdpi.com/2071-1050/12/14/5501>
18. Midgley, P. (2011). Bicycle-Sharing Schemes: Enhancing Sustainable Mobility in Urban Areas. *Comm. Sustain. Dev. 19th Sessions*, pp. 1–26. Available at: [https://www.un.org/esa/dsd/resources/res\_pdfs/csd-19/Background-Paper8-P.Midgley- Bicycle.pdf](https://www.un.org/esa/dsd/resources/res_pdfs/csd-19/Background-Paper8-P.Midgley-Bicycle.pdf)
19. Munkacsy A., Monzon A. (2017). Potential User Profiles of Innovative Bike-Sharing Systems: The Case of BiciMAD (Madrid, Spain). *Asian Transport Studies*. Retrieved from: <https://www.jstage.jst.go.jp/article/eastsats/4/3/4_621/_article>
20. Pang Z., Chen Q., Tian j., Zheng L., Dubrova E., (2013). Ecosystem analysis in the design of open platform-based in-home healthcare terminals towards the internet-of-things. *15th International Conference on Advanced Communications Technology (ICACT)*, pp. 529-534. Available at: <https://ieeexplore.ieee.org/abstract/document/6488244>
21. Shachak, A., Kuziemsky, C., Petersen, C. (2019). Beyond TAM and UTAUT: future directions for HIT implementation research. *Journal of Biomedical Informatics*, 100, 103315. doi: [10.1016/j.jbi.2019.103315](https://doi.org/10.1016/j.jbi.2019.103315).
22. Tabachnick, B. G., Fidell, L. S. (2013). *Using Multivariate Statistics* (6th ed.), Boston, MA: Person.
23. United Nations (2000). United Nations Millennium Declaration. General Assembly resolution 55/2. Available at: <https://www.ohchr.org/EN/ProfessionalInterest/Pages/Millennium.aspx>
24. Urry J. (2008). Climate change, travel and complex futures. *The British Journal of Sociology 2008*, 59 (2). Available at: <https://www.lancaster.ac.uk/staff/tyfield/urry08bjs>
25. Venkatesh, V., Thong, J. Y., Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MOUSE quarterly*, pp. 157-178. doi: [10.2307/41410412](https://doi.org/10.2307/41410412).
26. Venkatesh, W., Morris, M. G., Davis, G. B., Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, pp. 425-478. [doi: 10.2307/30036540](https://doi.org/10.2307/30036540).