THE REPUBLIC OF TURKEY
İSTANBUL KÜLTÜR UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

SMART CITY ROADMAP FOR ISTANBUL

MASTER OF SCIENCE THESIS

by Mohammad Feroz ALIZAI

1800000777

Department: Industrial Engineering

Program: Engineering Management

Supervisor: Assist. Prof. Dr. Mehmet Nurettin Uğural

DECEMBER 2021

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Mohammad Feroz ALIZAI

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LIST OF SYMBOLS

CISCO	Commercial & Industrial Security Corporation
EU	European Union
GHG	Global greenhouse gas
ICT	Information and Communication Technologies
IoT	Internet of Things
ITS	Intelligent Transportation Systems
ISBAK	Istanbul IT and Smart City Technologies Inc.
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
UN	Unite Nations
GHG	Green House Gas
R&D	Research and development
STSC	Smart Traffic Signal Control System
YÖK	Council of Higher Education in Turkey
PGI	Parking Guidance Information
MEMS	Micro Electric Mechanics System

Üniversite	**: İstanbul Kültür Üniversitesi**
Enstitü	**: Lisansüstü Eğitim Enstitüsü**
Anabilim Dalı	**: Endüstri Mühendisliği**
Programı	**: Mühendislik Yönetimi**
Tez Danışmanı	**: Dr. Öğretim Üyesi Mehmet Nurettin Uğural**
Tez Türü ve Tarihi	**: Yüksek Lisans – Aralık 2021**

ÖZET

İSTANBUL ŞEHRİ İÇİN BİR AKILLI ŞEHİR YOL HARİTASI

Mohammad Feroz ALIZAI

Artan nüfus ve hızlı kentleşme, dünya genelindeki mega şehirlerde yarattığı çevresel etkilerin yanı sıra trafik sıkışıklığı ve bu sıkışıklığın neden olduğu kazaları da beraberinde getirmektedir. Dünyanın en sıkışık ilk beş şehri arasında yer alan mega şehir İstanbul'da yaşayanlar her yıl yaklaşık 200 saatini trafikte geçirmektedir. Özellikle İstanbul gibi mega kentlerde bu zorluklarla başa çıkabilmek için şehirlerin daha akıllı hale gelmesi ve ulaşım sistemlerini iyileştirmesinin zorunluluk haline geldiği düşünülmektedir. Tespit edilen bu eksikliği giderebilmek adına, İstanbul kentine özel bir bakış açısıyla akıllı şehir bağlamında akıllı ulaşım gelişimini araştırılması ve analizi amaçlanmıştır.

Araştırmada bibliyometrik arama oluşan üç aşamalı sistematik literatür taraması kullanılarak önceki çalışmaların gözden geçirilmesini, sınıflandırılmasını ve çalışma sonucunda bir yol haritası önerilmesi amaçlamıştır. Akıllı şehirler için yapılan sistematik araştırmalar Scopus veri tabanı kullanılarak gerçekleştirilmiş ve bibliyometrik analiz sonucunda 27.431 adet kayıt tespit edilmiştir. PRISMA yönergeleri kullanılarak yapılan kalite değerlendirmeleri sonucu bu çalışma için belirlenen gerekli kriteri karşılayan 27 makale analiz için seçilmiştir. Aynı şekilde VOSviewer yazılımının desteğiyle yapılan bibliyometrik analiz sonuçları doğrultusunda, akıllı şehirler ile ilgili potansiyel araştırma alanlarının akıllı ulaşım, IoT, sensörler ve büyük veri olduğunu ortaya çıkarılmıştır.

Bu araştırmanın bulguları, akıllı şehir uygulamaları konusunda yeterli sayıda araştırma olmadığına işaret etmekle birlikte çalışmanın önemli bir sonucu, daha güvenli, emisyonsuz,

daha temiz ve sürdürülebilir bir akıllı şehir inşa etmek ve trafik sıkışıklığını azaltmak için içerisinde hava taksi dronlarının, elektrikli ve otonom araçların yer alacağı teorik ve ampirik araştırmalara daha fazla ihtiyaç olduğudur.

Anahtar Kelimeler: Akıllı şehir, Akıllı Ulaşım, Sistematik İnceleme, Yol Haritası, Proje Yönetimi

University	**: İstanbul Kültür University**
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ABSTRACT

SMART CITY ROADMAP FOR ISTANBUL

Mohammad Feroz ALIZAI

Growing population and rapid urbanization brought challenges like traffic congestion, environmental impacts, energy consumption, and road accidents to cities across the globe. Istanbul is among the top five congested cities in the world where its residence spends almost 200 hours every year in traffic congestion, to cope with these challenges, cities must take undertake a shift to become smarter and improve their transportation systems. Therefore, this study seeks to explore and analyze smart transportation development in the smart city context with a particular view on Istanbul city to fill this shortage.

This study which is a three step systematic literature review consisting of bibliometric analysis from most cited Scopus publications in the last couple of decades, aims to review and classify previous studies by using a systematic literature review approach following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Along with systematic literature review 27,431 records from the Scopus database were identified and after quality assessments by using PRISMA guidelines, inclusion and exclusion criteria 27 studies were selected for the analyzes and likewise, bibliometric analysis results with the support of VOSviewer software, revealed that smart cities are interrelated with smart transportation, IoT, sensors, and big data. Furthermore, the results introduce a roadmap and suggest that in order to build future cities in a more sustainable way, air taxi drones, electrical and autonomous vehicles will result in a safer, emission-free, and cleaner smart city and requires the theoretical and empirical attention of researchers.

Taken together, this study offers valuable insights and implications into evaluating smart city from a transportation perspective to support city leaders, policymakers, and local governments to reduce traffic congestion and develop new emerging technologies.

Keywords: Smart city, Smart Transportation, Systematic Review, Roadmap, Project Management

1. INTRODUCTION

Over the last couple of decades, the concept of the “smart city” has grown in popularity in academic literature and global politics. In fact, cities play a critical role in global social and economic elements as well as having a substantial environmental influence (Mori & Christodoulou, 2012). Moreover, the world is urbanizing swiftly, according to UN (2011), more than half of the worldwide population lives in cities, and by 2050, almost 70 % of the world's population will live in cities, making it an industrialized globe, and this pattern is projected to continue. According to the UN, the shift from a predominantly rural to a predominantly urban population will continue over the next two decades, adding additional strain on the city’s infrastructure and resources, while the world's urban population would have increased 1.5 times to 6 billion people by 2045 (UN, 2020). City leaders must take action quickly to prepare and plan for the growth and have the basic facilities, amenities, and better living conditions that their fast-growing communities and populations need. Furthermore, a rapidly rising population and an increasing need for services and infrastructure have pushed city planners, politicians, and government officials to investigate potential solutions to rapid urbanization concerns. Although the challenges for our cities around the world remain diverse, spanning from a lack of adequate transportation infrastructure to inadequacy of sanitation and drinking water supply to enhanced quality of life, urban planners and managers are unanimous in proposing smart and high-tech solutions to meet the challenges and implement smart city management. Furthermore, as a requirement for the development of smart cities, scientists discovered a novel strategy for leveraging high-tech tools to address current problems in cities and thus improve the overall quality of life (Albino et al., 2015). Many cities are still searching for strategies and implementations with a significant emphasis on technology, community engagement, and openness to deal with the surge of new immigrants and ensuring the standard of living environments for their inhabitants and also cities that want to become smart should create strategic plans and stick to them (Nam & Pardo 2011). Besides, cities of urban developed areas with a large population are significant in the world because human social and economic interests have converged there (Mori & Christodoulou 2011).

According to UN surveys, more residents now live in cities than in rural areas for the first time in history and global population increase is projected to take place almost entirely in towns and cities over the next three decades. The number of people living in cities is projected to increase, from 4.4 billion todays to 6.7 billion in 2050 (UN-Habitat, 2020).

Indeed, for achieving smart city status, smart transport is a key case for it also smart cities need smart transportation. While, according to Bamwesigye & Hlavackova (2019), both smart city and smart transport terminologies in terms of outputs and elements have a lot in common and both aim at achieving better living conditions for urban communities as shown in Figure 1.1.

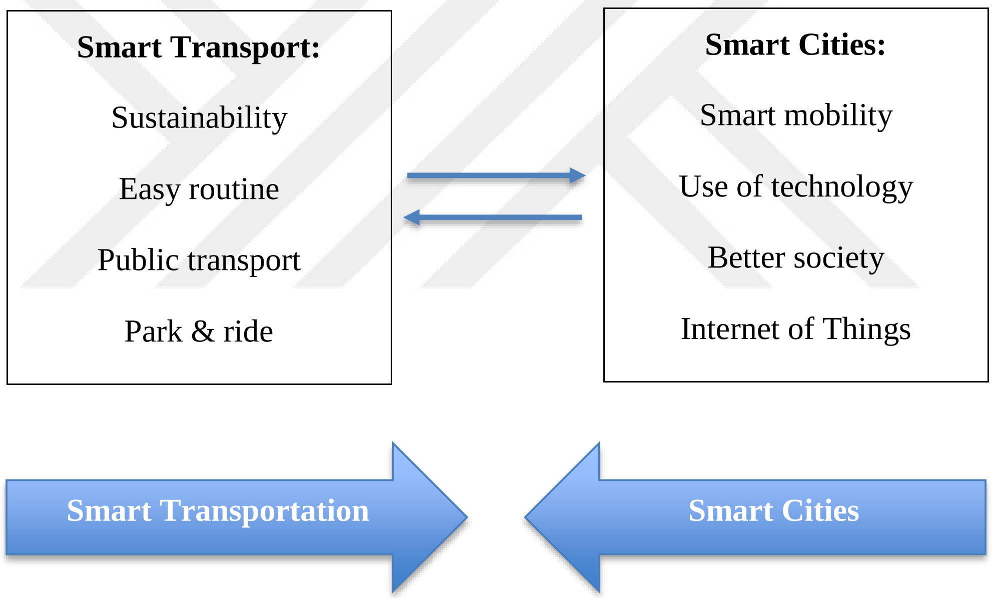

Figure 1.1: Smart cities and smart transportation

1.1.Background information

Since the late 1980s, the rise of information technology has had a significant impact on our culture, especially in terms of making our cities more smarter and knowledge-based. The word "smart" first appeared in the 1990s, according to the growth of information society with a focus on information and communications technology, concerning new services and infrastructure and their potential effects on society (Albino et al., 2015).

Furthermore, from the first publications on the topic in the late 1980s through the recent boom in smart city publications, the notion of a "smart city" has been influenced in the literature that stretches over 30 years. The definition was first used and the definition was established between 1985 and 1995, but it wasn't until after 2000 that it was systematically included in urban construction, planning, technology, and engineering works of literature. According to Google Scholar, the word "smart city" was first used in the 1988-1990 timeframe to describe advances in urban mobility enabled by information technology, the use of IT to provide city services, and cities' improved success in terms of environmental, economic, and social goals (Komninos, 2018).

The concept of a smart city for Istanbul have lunched by ISBAK (Istanbul Computing and Smart City Technologies Inc.) which was founded by the Istanbul metropolitan municipality in 1986 to provide project design and execution services through traffic and device engineering also, ISBAK provided vehicle maintenance and repair services to the Istanbul metropolitan municipality, as well as traffic signalization work in Istanbul. In 1995, it expanded its scope of operations by establishing a research and development (R&D) department and began professional work in the field of Smart or Intelligent Transportation Systems with traffic signalization. In fact, ISBAK with a slogan of “Architect of Smart Cities in Turkey” per its mission and value in order to transfer its expertise in intelligent transportation systems through smart city solutions. The intelligent transportation systems design, R&D programs, and implementations provide the means for the community to become cleaner, more convenient, and environmentally friendly. Consequently, ISBAK develops emerging and domestic innovations in the areas mentioned below, intending to resolve traffic issues in Istanbul smart city Technologies and Application; Intelligent Transportation Systems, Transportation Planning and Geographical Information Systems, Intelligent Lighting System, Communication-Vision and City Safety Management System, Tunnel Management systems are all examples of the smart or intelligent transportation system (ISBAK Inc., 2020).

Thus, this chapter introduced the topic of smart city and smart transportation, and after a brief introduction of the background and smart city concept, here the purpose and the problem statement of this study are stated in the following. Subsequently, research questions which this study will try to answer and limitations with addressing these questions are presented. In addition, the importance of this study, reasons for taking on this study, and expected results are covered in this chapter.

1.2.Problem statement

Many cities have set up pilot projects to explore emerging solutions that can help solve urban planning challenges, increase the efficiency of urban facilities, and improve citizens' quality of life. Yet, after the pilot stage, many of the projects fade out and struggle to provide scalable solutions that lead to long-term sustainable urban development. Meanwhile, municipalities usually fund these projects that are also referred to as "smart city" projects that are funded by subsidies and managed through partnership (Winden & Buuse, 2017).

Smart transportation is one of the smart city elements. Any of the most pressing issues facing smart cities today are improving mobility, maintaining accessibility, and reducing traffic congestion. Many city officials are looking at smart transportation options to reduce traffic congestion and maximize the usage of city public transportation in response to these challenges (Pawłowska, 2018).

Istanbul looks furious for its traffic and the important problem in Istanbul is transportation. Researchers estimate that traffic congestion costs the global economy close to 3 billion dollars a year, that is from people stuck in their cars, delays in the delivery of goods, and the fuel that cars burn (Moneytalks, 2019). Moreover, according to TomTom’s Traffic Index (2020), in the rankings are Moscow (54%), Mumbai (53%), Bogota (53%), Manila (53%), and Istanbul (51%), making up the top five most congested cities in the world and Istanbul city residence loses 200 hours per year in a rush hour due to traffic congestions. Furthermore, in Istanbul, there is also a shortage of research studies on the smart city from a transportation perspective, as well as how appropriate approaches will lead to the development of smart city projects. In addition, transportation and traffic congestion are the great challenges smart cities are currently facing, and also there is a lack of a roadmap for Istanbul city.

1.3.Aim of the research

There's an increase in transportation and traffic congestions faced cities nowadays, Istanbul is among the top five congested cities in the world and the residence spends almost 200 hours every year in traffic congestion which costs the economy and results in environmental impacts, collisions & accidents, and energy loss due to of fuel consumptions, to cope with these challenges, cities must take undertake a shift to become smarter and improve their transportation systems. Moreover, there is also a shortage of research studies on the smart city from a transportation perspective and a lack of a roadmap for Istanbul city.

The main aim of this study is to, analyze and explore the concept of the smart city through a lens of transportation, present transport as a component of the smart city, show smart transportation role in reducing traffic congestion, and developments for the future smart transportation within the context of a smart city. To fulfill this aim, this study uses a systematic literature review based on PRISMA guidelines and bibliometric analysis from the most cited publication in the last couple of decades. Furthermore, this study, taken together offer valuable insights and implications into evaluating smart city from a transportation perspective to support city leaders, policymakers and local governments to reduce traffic congestion and develop new emerging technologies.

Finally, this research introduces a roadmap and then provides recommendations for Istanbul city and this roadmap will contribute to the preparation of Istanbul for the future and keeping up with development and a better understanding of the smart city.

1.4.Research question

The following research intends to answer the following research questions:

RQ1: What are the publication trends in the field of smart city and what recommendations can be made after examining the smart city projects publications from a transportation perspective in the last two decades in the world to help Istanbul city reduce traffic congestion and efficiently towards becoming a smart city?

RQ2: What are the technologies that will impact transportation and traffic problems in near future?

1.5.Significance of the research

There are few studies of smart cities and smart transportation for Istanbul and an investigation of the smart city from the lens of transportation is considered to provide a new insight for Istanbul in order to become a smart city. Moreover, the number of studies about smart cities which are expected to give a journey and direction for Istanbul is frankly just a few. According to the Council of Higher Education Thesis Center's (YÖK) records; studies on smart cities from the perspective of transportation began in Turkey in 2012, and the first thesis with "Smart Transportation system" in the title was completed in 2012. There have been a total of 5 theses completed in Turkey until now, all including master's thesis with "Smart Transportation" in the title.

Smart transportation can save time, cost, and lives if they are properly planned and implemented. In this way, the construction of smart cities will play a greater role in promoting economic growth. This research will be beneficial for the development of smart transportation and contribute at a scholarly level and add value to the current body of knowledge and be expected to give direction for more studies in this area.

1.6.Scope and structure of thesis

Our scope is set within smart city project from a transportation perspective for Istanbul city. Further, our aim is also to develop recommendations for smart city practitioners, to develop the smart transportation capacity of their smart city approach. As a result, our target audience will be smart city practitioners who are already familiar with the idea and working within the concept but want to reduce traffic congestion, develop their urban planning processes in order to make their city smart and sustainable. Moreover, the current research focuses on the smart transportation perspective of the smart city in Istanbul. In order to achieve and ensure the fulfillment of the main aim of this research, and answer the research questions, the thesis report is divided into five main chapters:

Introduction: focuses on smart city in general terms. This chapter provides a summary of the subject addressed in the research, problem statement, defines the aim of the study, structures the research questions, and provides the significance of the study and its scope.

Literature review: focuses on the concept of the smart city in a general sense and gives a review of the history of smart cities as well as their importance from relevant journals, books, and publications and latest studies about smart cities is presented in this chapter.

Methodology: reviews the methodologies used to collect data for this thesis. This chapter includes the research method, data collection, and analysis processes.

Implementation and results: the data analysis and interpretation are addressed in this chapter and at the end of chapter 4 smart city roadmap is presented for Istanbul.

Conclusion: is a summary of the research is presented, along with the final findings. Recommendations concerning the implementation and the numerical results are provided, and future recommendations for research are given.

2. LITERATURE REVIEW

The smart city concept emerged throughout time with a variety of vocabulary and views as a means to define urban technology progress. Furthermore, scholars did not coin the term "smart city" to describe the concept until the late 1990s, when they began approaching cities and information communications technologies (ICT) from a variety of perspectives and using a variety of terms to try to characterize ICT project installation within the urban area and use of ICT to resolve local problems (Anthopoulos, 2017). As shown in Figure 2.1, The word "**web**" or "virtual city" was used to describe local ICT network initiatives in 1997, and also introduced the concept and term "digital city," which referred to a "virtual city" that has been considerably more equitable and discursive.

Figure 2.1: Smart city evolution timeline (Anthopoulos, 2017).

2.1.Cities

"The 19th century was a century of empires, the 20th century was a century of nation states. The 21st century will be a century of cities." – Wellington E. Webb, former Mayor of Denver, Colorado (Nowicka, 2014).

Cities have a tremendous influence on the environment and play a crucial role in global social and economic dynamics (Mori & Christodoulou, 2012). Cities use between 60% and 80% of global energy and account for a significant portion of global greenhouse gas (GHG) emissions (UN, 2011). Moreover, cities are tremendous drivers of economic growth, fueled by large concentrations of specialized talents and extensive interpersonal interactions. However, the benefits of urbanization are matched with enormous environmental problems, with cities accounting for more than 70% of GHG emissions and 60-80% of worldwide energy consumption today (ITU, 2015).

Although most people can grasp the term city based on their personal experiences, but a uniform definition is difficult to come by and a city is defined as a metropolitan area with a population size of 1,500 inhabitants per square mile, however, this varies by countries (Anthopoulos, 2017).

Furthermore, cities are prioritizing its urban innovation ecosystems, shifting away from their traditional urban characteristics or towards innovating "green," "smart," "open," "intelligent," and "innovative," with the goal of achieving environmental and social sustainability (Zygiaris, 2013).

2.2.Smart City definitions

Over the last two decades, the smart city, concept has grown in popularity in worldwide scientific and political literature. To comprehend the concept, it's important to first understand why cities are such an important part of the future., and there are several definitions of smart cities. Thus, by replacing "smart" with other qualities such as "intelligent" or "digital" to get a variety of ideas (Albino et al., 2015).

Although the phrase "smart city" is widely used in public and academic publications, no definitive definition exists. Many of these definitions focus on the features of a "good" city, while others place a greater emphasis on technology, Table 2.1 indicate five definitions of smart city (Allam & Newman, 2018).

Table 2.1: Smart city definitions (Allam & Newman, 2018)

No:	Definitions:
1	A city that governs and combines its critical conditions and infrastructure, such as, bridges, roads, tunnels, trains, subways, airports, seaports, communications, water, electricity, or even mega structures," according to the definition. Manage your resources, organize preventative operations of maintenance, and keep an eye on security to ensure that your residents receive the best possible service.
2	A city that considers the economic, governance, mobility, people, environment, and quality of life, and is founded on the smart integration of self-aware inhabitants' assets and activities.
3	A city that by optimizing resources, performing preventive maintenance and monitoring safety aspects, while controlling and integrating important conditions and infrastructure (such as roads, bridges, tunnels, railways, subways, airports, seaports, communications, water, electricity) to maximize its citizens to provide services to cities and even large buildings.
4	A city is a network of physical, information technology, social, and economic infrastructure that is used to tap into the collective intelligence of the city.
5	A 'smarter' city is one that seeks to be more efficient, sustainable, equitable, and livable.

Moreover, according to Mkrtychev et al. (2018), there are different definitions for Smart Cities as following:

- Definition 1: Smart cities are a new concept and paradigm for city design, building, management, and smart services that use the latest generation of information technology.
- Definition 2: Smart cities are described as places that efficiently integrate physical, digital, and human systems in order to provide residents with a future that is sustainable, wealthy, and egalitarian.
- Definition 3: A smart city that is sustainable is an innovative city that combines information and communication technology and other instruments to improve quality of life, use of urban services, and competitiveness while meeting present and future demands economically, socially, and environmentally.
- Definition 4: A smart city is one that dramatically accelerates its economic, economic, and environmental development (sustainability) by fundamentally improving how it interacts with society, how it uses participatory leadership methods, and how it collaborates across disciplines.
- Definition 5: A smart city is one that excels in six major areas of urban development and is built on the premise that "smart" refers to a combination of resources and actions taken by self-aware and knowledgeable residents.

Based on these definitions, what are the primary qualities of a smart city? The fundamental indicator of a smart city, according to the definition, is the developed and widely utilized technology utilized in the city economy, in the planning and management of urban services. Definition 2 is a broad, though not scholarly, definition. It is, first and foremost, a symbol of the integration of several structural systems. Definition 3 aims to replace the term "smart city" with "innovation city." As in Definition 1, the developed IT technology are the key trademark of the smart city in Definition 3. In contrast to definition 1, "additional interpretations" are given, although their nature is not specified. Definition 4 highlights the fast pace of economic and environmental development. Definition 5 is a shift from the previous four qualitative definitions of smart city to a quantitative definition (Mkrtychev et al., 2018).

Nam and Pardo (2011) investigated at the many definitions of the term "smart" in the context of the smart city, "Intelligence" is a more user-friendly phrase in marketing language than the elitist phrase "clever," which is generally confined to having a fast thinking and being attentive to input. According to certain interpretations, "smart" includes the term "smart," because intelligence is only accomplished when an intelligent system adapts to the demands of users.

In Table 2.2, Albino et al. (2015), present many definitions and interpretations of the term "smart city." However, the table demonstrates that the term "smart city" is no longer limited to ICT dissemination, but also includes social expectations and wishes.

Table 2.2: Definitions of a smart city Definition Source (Albino et al., 2015)

Authors:	**Definitions:**
Bakıcı et al. (2013)	A smart city is an advanced and technologically city that is combining people with information and urban characteristics to create a more sustainable, greener competitive and imaginative city, while improving the quality of life as well.
Barrionuevo et al. (2012)	Smart cities use all available technologies and resources carefully and in a coordinated way to build interconnected, livable and sustainable urban centers.
Caragliu et al. (2013)	The city is smart whenever it invests in capital, as well as traditional (transportation) and modern communication (ICT) infrastructures, to support long-term growth in the economy and a good quality of life through participatory governance and resource management.
Cretu (2012)	There are two primary research concepts: 1) Smart cities should apply new thinking paradigms to everything connected to government and the economy, and 2) smart cities should use sensor networks, ICT, real-time data, smart gadgets, and ICT integration to every element of human presence.

Table 2.2: Continued

Chen (2010)	Smart cities use communications and sensors integrated in urban infrastructure to increase everyone's quality of life by maximizing the use of power, transportation, and other logistical tasks that support daily life.
Harrison et al. (2010)	A metropolis in which ICT, social, business infrastructure and physicals are linked to utilize the collective intelligence of the city.
Washburn et al. (2010)	Use intelligent computer technology to make the city's core infrastructure components and services smarter, more interconnected and more efficient (including municipal, educational, medical, public safety, real estate, transportation and public utilities).

In light of the above, the smart city idea is founded on the basic characteristics of the popular ICT vision, namely, computing's universality in urban systems, the extensive usage of ICT in urban settings, and the various benefits and opportunities it offers cities and residents (Bibri and Krogstie, 2017). Moreover, a city's "smartness" represents its capacity to pool all resources, effectively and smoothly attain goals, and achieve its defined goals. However, if one wants a precise definition of a smart city, he will not be able to discover one, but will instead look for numerous possibilities, resulting in confusing meaning (Ansopoulos 2017).

The "smart city" idea is defined in the literature as the future secure, dependable, environmentally friendly, and efficient city core, equipped with contemporary infrastructure such as sensors, electronic devices, and networks to enable long-term economic growth and high-quality living. Because it has an impact on prolonging urban expansion, most cities in Europe and the United States have utilized or will employ the smart city technique (Bakıcı, 2013). Furthermore, the ultimate goal of a digital city is to create an environment that encourages information sharing, collaboration, and integrated experiences across the city (Albino et al., 2015).

2.3.Smart City Components

Smart cities are not just road communication with the vehicles to help reduce traffic congestion, it's intelligent, sustainable and connected. Moreover, smart cities are made up of components, similarly according to Giffinger & Gudrun (2010), smart city has six components: a smart economy, smart people, smart transportation, a smart environment, smart lifestyle, and smart governance. As shown in Figure 2.2, these six components were deemed to be the relevant group describing a smart city. Similarly, Lombardi et al., (2012), have identified the six components of smart cities, each with different aspects as shown in Table 2.3. The smart economy has been identified with the presence of industries in the field of ICT, smart people with related aspect of education, smart governance with aspect of e-democracy, smart mobility related to the usage of ICT in modern transport technologies to develop city traffic.

Table 2.3: Smart city components and aspects (Lombardi et al., 2012)

Components	**Related aspects**
• Smart Mobility • Smart People • Smart Economy • Smart Governance • Smart Environment • Smart Living	• Transportation, Logistics & Infrastructures • Education • Industry and Innovation • E-democracy and Empowerment • Sustainability & Efficiency • Security and Standard

SMART ECONOMY
(Competitiveness)

- Innovative spirit
- Economic image & trademarks
- Productivity
- Flexibility of labor market
- Entrepreneurship
- International embeddedness
- Ability to transform

SMART PEOPLE
(Social and human capital)

- Social and ethnic plurality
- Level of qualification
- Affinity to lifelong learning
- Flexibility
- Creativity
- Cosmopolitanism/Open mindedness
- Participation in public life

SMART GOVERNANCE
(Participation)

- Participation in decision-making
- Public and social services
- Transparent governance
- Political strategies & perspectives

SMART MOBILITY
(Transport)

- Local accessibility
- (Inter-)national accessibility
- Availability of ICT-infrastructure
- Sustainable, innovative and safe-
  Transport systems

SMART ENVIRONMENT
(Natural resources)

- Environmental protection
- Lack of pollution of natural conditions
- Pollution
- Sustainable resource management

SMART LIVING
(Quality of life)

- Health conditions
- Cultural facilities
- Housing quality
- Individual safety
- Education facilities
- Touristic
- Social cohesion

Figure 2.2: Components of smart city and factors (Giffinger & Gudrun, 2010)

In this regard, Antpoulos et al. (2016), conducted a comparative examination of conceptual models accessible in smart cities as indicated in Figure 2.3 and these models include an eight (8) components of smart city and depicts a physical-cyber integration that, by combining typical views, addresses:

1. Smart transportation (also known as Smart Mobility): denotes to transport systems that are outfitted with strong integrated monitoring and real-time control systems.
2. Smart infrastructure: applies to municipal infrastructures (such as water and energy networks, highways, and buildings) furnished with smart technology (such as sensors, smart grids, and so on).
3. The term "smart environment": refers to the use of ICT innovation and connectivity to preserve and manage natural resources (waste management systems, recycling, emission control, sensors for pollution monitoring, etc.).
4. The term “smart services”: are defined as the use of technology and information and communication technology (ICT) in sectors such as health, education, tourism, safety, response control (monitoring), and delivering services throughout a city.
5. Smart governance: this includes the establishment of smart government in metropolitan areas, as well as technology engagement and interaction.
6. Smart people: actions that increase creativity and innovation in people.
7. Smart living is the use of innovation to improve the quality of life and livability in urban areas.
8. Smart Economy: increasing trade, employment, and urban growth via the use of technology and innovation.

Furthermore, these components are interrelated, and data collection and ICT infrastructure should be incorporated in hard city infrastructure to provide intelligent services to urban actors, as shown in Figure 2.4, while sovereignty is required to organize the subsystems and succeed in the smart city mission (Anthopoulos, 2017).

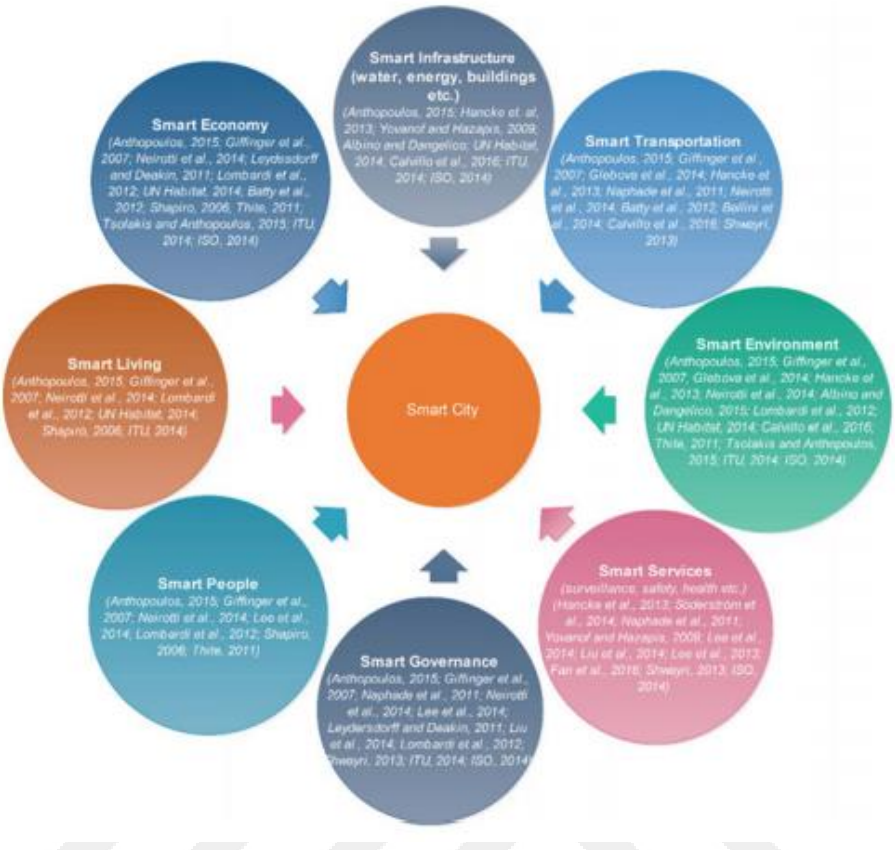

Figure 2.3: Smart city components (Anthopoulos, 2017)

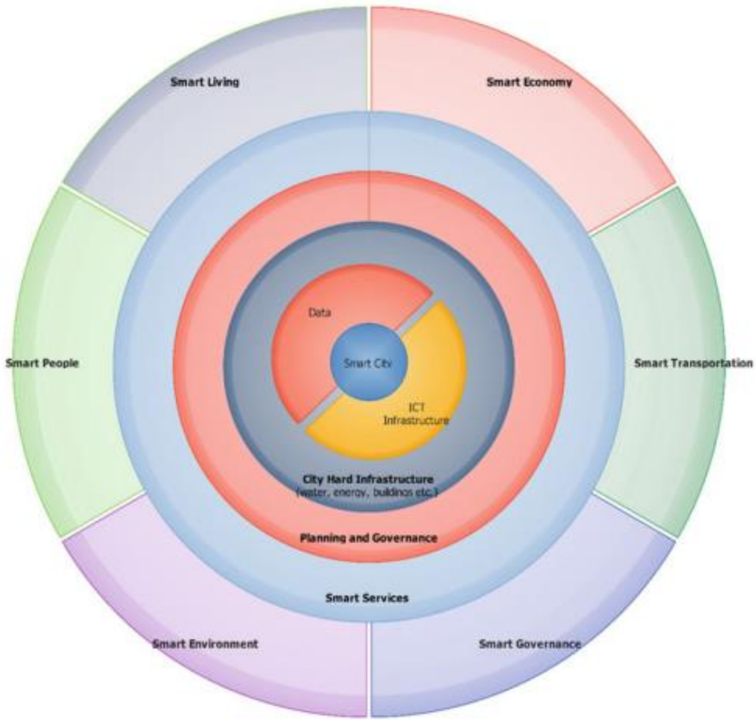

Figure 2.4: Smart city conceptual system (Anthopoulos, 2017)

In addition, the smart city design is described at a high level by (ITU-T, 2015), with the meta architecture consisting of five levels, as depicted in Figure 2.5.

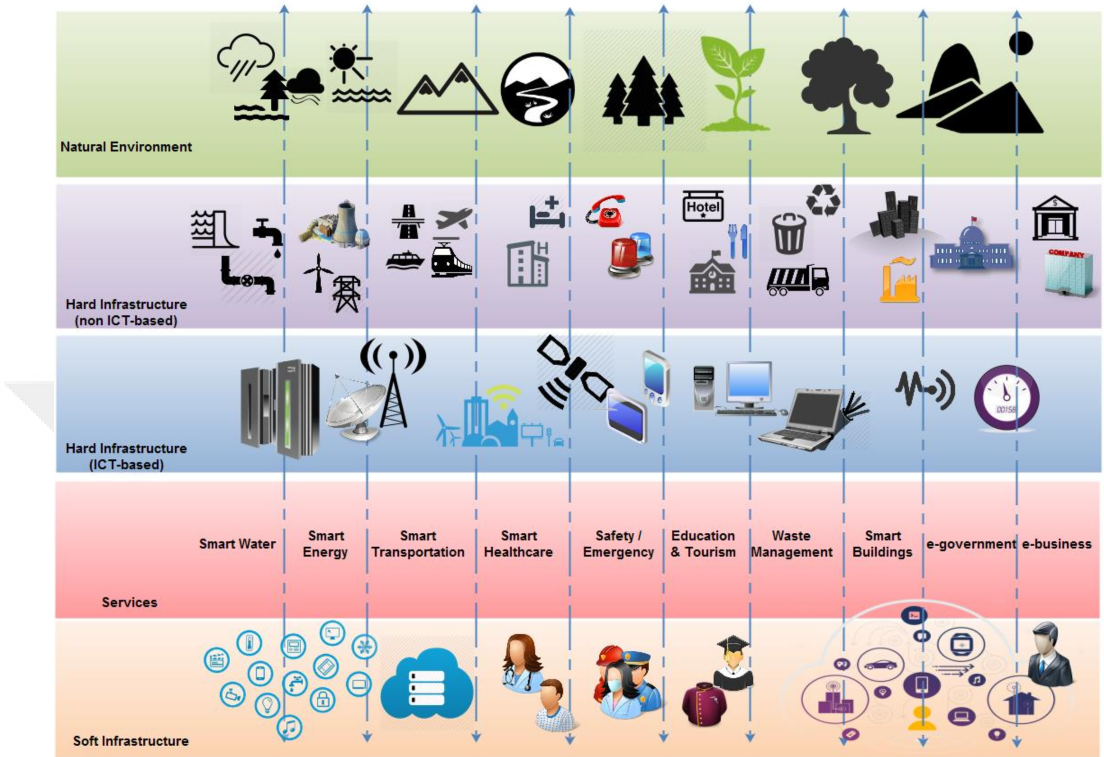

Figure 2.5: Smart city Meta-architecture (ITU-T 2021, 2015)

Furthermore, a smart sustainable city may also be thought of as a system comprised of its subsystems and ICT architecture (illustrated in Figure 2.6), with each subsystem representing a distinct set of sustainable urban services

Figure 2.6: Smart city Subsystems of ICT architecture (ITU-T 2021, 2015)

2.3.1. Smart Transportation

Smart transportation concept has emerged, with the emergence of smart cities and it is in accordance with the UN stated sustainable development goals and also some of the fundamental reasons for smart transportation including new route optimization to minimize traffic congestion and reduce ecological footprints as well (Paiva et al., 2021). Moreover, smart transportation is one of the primary engines propelling progress. This has been a long-standing tendency. Smart cities must have dependable transportation infrastructure in order to achieve sustainable growth. The driving aspect of a smart city is the integration of human capital, infrastructure, and social capital in order to achieve more sustainable economic growth and a higher quality of life for urban residents. In other words, intelligent transportation is a driving element in the realization of smart cities (Bamwesigye & Hlavackova 2019).

In addition, smart transportation technologies include those employed in the implementation of parking management systems, intelligent transportation systems, and traffic management systems is also known as intelligent transportation systems (ITS) and technological information, telecommunications, location, and automation, are designed to improve urban traffic safety and efficiency while reducing environmental impact (ITU, 2015).

Smart or intelligent transportation systems (ITS), aim to provide services connected to various modes of transportation and traffic management, allow users to be better informed and use safer, more coordinated, and "smarter" transportation networks and include sophisticated telecommunications and hybrid communications, such as IP-based communications and direct Ad-Hoc connection between cars and infrastructure (ETSI, 2016). Similarly, ITS Includes telecommunications and all sorts of communications in cars, between cars (e.g., car-to-car), and fixed places (e.g., car-to-infrastructure) are all part of this system. ITS, on the other hand, is not restricted to road transport; it also involves the use of ICT for rail, river, and air transportation, including navigation systems (ITU-T, 2015).

Besides, smart applications such as smart transportation, smart energy, smart environment, smart planning, smart design, smart grid, smart traffic, smart education, smart healthcare, and smart safety are enabled by big data analytics and context–aware computing (Bibri & Krogstie 2017). Moreover, to allow a better intelligent transportation system, our next study focus should be on the system's real "smart" behaviors, which are constructed using machine learning algorithms and built on top of IoT infrastructure (Li et al., 2021).

All over, smart transportation is one of the components of a smart city and some of the most difficulties in smart cities today include improving mobility or transport, assuring access, and minimizing traffic congestion. Many city planners are looking at smart mobility solutions to take advantage of congestion as well as the best utilization of public transit to solve these difficulties (Pawłowska, 2018).

2.4.Experiences of Smart Cities

At the start of 2012, around 143 automated projects designated for smart cities have been finished or are in the process of being completed. Cities in North America (35 projects) and Europe (47 projects) are currently implementing smart technology to address and fix such cities. Energy shortages, traffic bottlenecks, poor urban infrastructure, and various health and education concerns are among the difficulties. The European Union (EU) is spending heavily on smart city initiatives for cities such as Barcelona, Amsterdam, Berlin, Edinburgh and Manchester (Lee et al., 2014).

Further, smart city initiatives have been developed by the EU in a number of cities, including Amsterdam, Barcelona, Berlin, Edinburgh, Manchester. In the United Kingdom, Southampton claimed to be the country's first smart city over 15 years ago after establishing its own multi-purpose smart card for public transportation, leisure, and related transactions (Albino et al., 2015).

2.5.Smart City studies

In a year when numerous European cities were ranked, Singapore, Helsinki, and Zurich are included in the 2020 Smart City Index. Moreover, Smart City Index (2020) assesses cities according to economic and technical statistics, as well as individuals' assessments of their city' "smartness" shown in Table 2.4.

Table 2.4: List of top 25 smart cities (Smart Cities Index, 2020)

City	Smart City Rank 2020	Change	Smart City Rating 2020	SmartCity Rank 2019	Smart City Rating 2019
Singapore	1	▬ (0)	AAA	1	AAA
Helsinki	2	▲ (+6)	AA	8	A
Zurich	3	▼ (-1)	AA	2	AAA
Auckland	4	▲ (+2)	AA	6	A
Oslo	5	▼ (-2)	AA	3	AA
Copenhagen	6	▼ (-1)	AA	5	AA
Geneva	7	▼ (-3)	AA	4	AA
Taipei City	8	▼ (-1)	A	7	A
Amsterdam	9	▲ (+2)	A	11	A
New York	10	▲ (+28)	A	38	BB
Munich	11	new	A		
Washington D.C.	12	▲ (+19)	A	31	BBB
Dusseldorf	13	▼ (-3)	A	10	A
Brisbane	14	▲ (+13)	A	27	BBB
London	15	▲ (+5)	A	20	BBB
Stockholm	16	▲ (+9)	A	25	BBB
Manchester	17	new	A		
Sydney	18	▼ (-4)	A	14	A
Vancouver	19	▼ (-6)	A	13	A
Melbourne	20	▲ (+4)	A	24	BBB
Montreal	21	▼ (-5)	A	16	A
Hamburg	22	new	A		
Newcastle	23	new	A		
Bilbao	24	▼ (-15)	BBB	9	A
Vienna	25	▼ (-8)	BBB	17	BBB

2.5.1. Smart City Studies in Istanbul

Turkey, should prioritize smart city development notably Istanbul and these seven cities are not yet smart city, but they are now sustainable cities (Anadolu ajansi, 2019):

1. Istanbul
2. Bursa
3. Ankara
4. Eskisehir
5. Izmir
6. Denizli
7. Antalya

Moreover, Istanbul is Turkey's largest city and the country's hub, as well as an intercontinental metropolis due to its location on the Bosphorus Waterway in northern Turkey, between the Black Sea and the Sea of Marmara. This indicates that the commercial heart of the city is in Europe, while the rest of the city is in Asia. Istanbul's population is expected to reach 15,415,197 persons by 2021. Moreover, even though it has always had a huge population, Istanbul has expanded remarkably quickly in the previous 100 years and has always been one of the world's major cities throughout its lengthy history. Istanbul (Constantinople at the time) had a population of 400,000 to 500,000 people in 500 AD. Figure 2.7 (Appendix A), shows the population level and growth rate for Istanbul from 1950 to 2021. UN population projections are also included through the year 2035 (World population, 2021).

In addition, according to Gürcan (2016), Istanbul is Turkey's busiest metropolis as well as its economic, cultural, and historical hub and Istanbul is finishing and building large-scale projects, such as high-speed railway construction, Istanbul canal, Istanbul-Izmir highway, while the result of these investments will aid in the development of the city as well as the increase of the population. Moreover, Istanbul need smart city projects as soon as feasible, with Istanbul residence suffers from traffic congestion. However, IETT has begun certain smart city initiatives, and significant investment has been made. Built-in infrastructure is insufficient and environmental pollution, particularly marine pollution, is also at a high level. Smart-solutions are required, and the participation of Istanbul municipal authorities is important, to transforming Istanbul into a smart city.

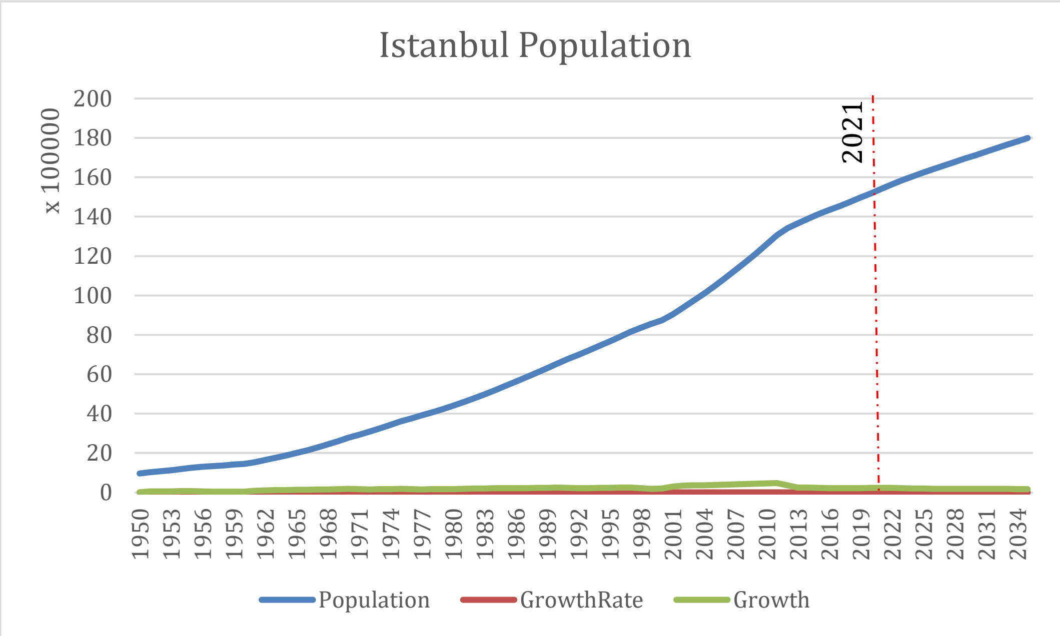

Figure 2.7: Istanbul population (World population, 2021)

2.6.Smart City challenges

According to Falconer & Mitchell (2012), cities around the world are facing challenges including:

1. Population growth
2. Economic growth that is polarized
3. A rise in GHG
4. Cut out and decreased budgets

Cities consumes over 70% of the world's resources, therefore in addition to urban population density and the intensity of related economic and social activity, cities are big users of energy resources and significant GHG emitters. The constructed environment, as a result, contemporary urban and academic debates continue to center on the role of sustainability in urban design and development in order to address the fundamental difficulties of rapid urbanization, the insecurity of existing urban forms, and future development. Cities are better prepared to respond to changing and challenging conditions when they take a long-term, sustainability-focused approach (Bibri and Krogstie, 2017).

Furthermore, these sustainability issues and dangers are not only serious in and of themselves, but are also linked. For example, the attraction of a city's information and communication infrastructure is crucial to mobile business and investment. The city's commercial network has a significant impact on transportation use. It uses a lot of energy and emits a lot of greenhouse gases, with building and transportation accounting for 25% of total emissions (Dirks & Keeling, 2010).

2.7.Smart City Solutions: Barriers to Implementation

Falconer & Mitchell (2012), outline a strategy that will assist key stakeholders, city and community participants: 1. Understand how the city functions; 2. Determine the city's goals and stakeholder responsibilities; and 3. Recognize the role of ICT in the city's physical assets. Furthermore, numerous problems limit the adoption of smart city solutions: the scalability of new technologies has not been established; technology challenges the current condition of urban operations; and different city departments' comprehension of technology is insufficient. The complexity of urban operations, budgeting, monitoring, and planning, on the other hand, is the fundamental impediment to implementing such solutions. Smart cities, on the other hand, provide potential to connect urban physical infrastructure ranging from urban services, transportation, and property development to urban services and introduced a framework by CISCO in addition, it focuses the city's use of ICT in response to population growth.; economic growth; a rise in GHG emissions (Falconer & Mitchell, 2012). Similarly, Anthopoulos (2017), introduced the following step for the framework:

Step 1: Gather information on smart city objectives as seen in Figure 2.8.

- Why is smart city effort useful for a city?
- What is the value gained as a result of the initiative or innovation?
- How should we proceed?
- What solutions do we use?
- What steps do we take?

- How can we implement the solutions?
- What policies and business models are needed?

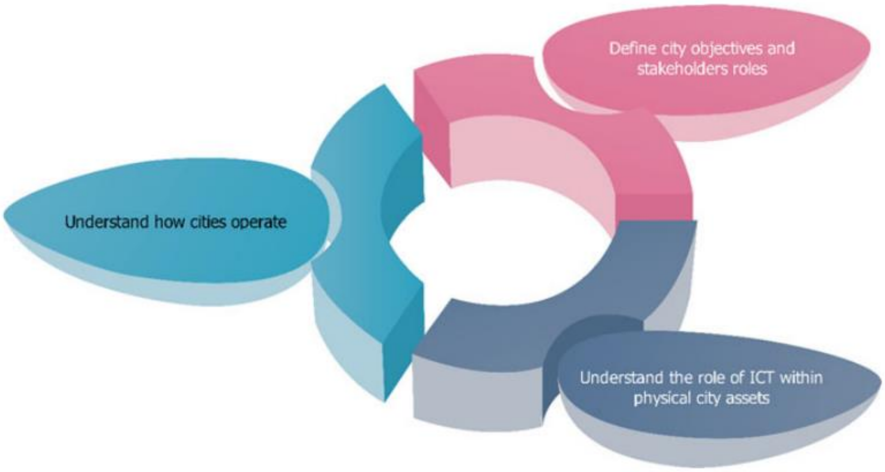

Figure 2.8: Defines the objectives of step 1 (Anthopoulos (2017)

Step 2: Gather information on the city

A smart city framework answers the following questions, which help to provide a more complete picture of the smart city:

- Who is responsible for many components of the city?
- Who directs and manages the behavior of the organizations that manage their components?
- How do different parts of the city interact with each other and other stakeholders?
- Stakeholders play an important role in the development of the smart city and they must be clearly identified and respected.
- What business models are needed to deploy smart solutions?
- What is the function of Information and Communication Technology (ICT)?
- What criteria are used to evaluate cities and initiatives?
- What is the government role?

Step 3: Define layers

The layers gather vital information about the smart city:

Layer 1: sets high-level smart city goals among city officials and stakeholders.

Layer 2: allocates cues to the city's goals to assess their potential and ultimately their achievements.

Layer 3: collects information about city components / assets on physical land, including their location and industry.

Layer 4: controls how to implement smart solutions and connects Layers 1 and 3.

Finally, Falconer & Mitchell (2012), introduce layers of smart city framework form bottom to top as illustrated in Figure 2.9.

Figure 2.9: Layers of smart city framework (Falconer & Mitchell 2012)

2.8.Road mapping

Road mapping is an attractive and practical method that is primarily a visual representation of the relationship between technology, company and market conditions (Probert et al., 2003).

Road mapping is a technique for combining corporate innovation and marketing by allowing the development of short- and long-term technological plans based on the interplay of commodities and technologies across time. A demand-driven technical planning process that matches market demands, an interaction management tool that aids in policy and strategic decision-making, and a collaborative approach to strategic development as a whole are all included in the definitions. Science and technology have an important role in product and company strategy. In a word, road mapping is a framework for establishing and defining technical development timelines, as well as a consistent and sensible method to picking technologies that meet the company's aims (Lee et al., 2013).

A survey of UK manufacturing companies found that 10% of large and medium-sized companies at the time had implemented the technology roadmap. 80% of these companies have used this method more than once or have actually worked continuously (Lee et al., 2011).

2.8.1. Roadmap development

Probert et al., (2003), noted that the technological roadmap involves three major business activities: strategy development, innovation, and operational processes, which are as follows:

- Strategy development: is the process of formulating the direction and general plans of the company in the future. The goals of the technology roadmap are undoubtedly the basis of this approach.
- Innovation: is the process of maintaining stability in the supply of new products, services, processes and support systems to ensure the long-term viability of a company. When new projects and services are expected to be launched in the market, the roadmap highlights their scheduled time.
- Operation: refers to the process of bringing existing projects and services to market. Efficient performance is the key to success.

Le et al., (2013), emphasized the basic design considerations of the road mapping process. First of all, the road mapping method needs to accurately classify the service equipment technology within the smart city framework. In addition, the type of alternative roadmap should be defined according to its purpose in the classification scheme in order to select the appropriate type for certain specific smart city applications. The roadmap should be able to showcase and assist product planning (the most frequent sort of roadmap item) in order to coordinate service delivery / capability and delivery of smart city services via devices that are supported by developing technologies. Second, research must be conducted to develop relevant templates for an integrated strategy, because the roadmap is used as a visualization tool to aid communication between diverse interest groups, it is required to build a roadmap in a standard style with various levels structured to upgrade new services, equipment, and technology and deliver effective service.

Petrick & Echols (2004), define road mapping a process of planning technology that can explore future technological paths and provide a framework for market integration and technological development. Companies use it to gather information from various sources and make dynamic short-, medium-, and long-term plans for R&D investment and new product and process development.

According to Probert et al., (2003), there are six types of technology roadmap plans:

1. Strategic evaluation: The roadmap model is used to collect, organize, and share information about the target area, as well as to identify strategic concerns.
2. Business reconfiguration: The roadmap model is used to examine the existing condition and review the results of a certain strategic aim.
3. Technology and Product Planning: The roadmap approach is used to develop an integrated product technology program that fulfills market and corporate expectations by choosing product features and technologies based on customer demand and priorities.
4. Process development: The roadmap model is used to monitor the flow of information between both the business and technical departments in order to optimize and enhance business processes like product development.
5. Research Network Development: The roadmap model is used to capture, create, and exchange information from both a business and technical standpoint, as well as to identify future requirements and application prospects, as well as existing research and network objectives.
6. Industry outlook: The roadmap template is used to identify difficulties and future technologies, as well as to record, create, and exchange information about industry and market trends and driving variables, before defining system performance measures (Probert et al., 2003).

Above all many studies have identified the smart city in a broad perspective, while other studies focus on the different factors regarding smart city developments. Therefore, more focused studies are needed from a transportation perspective.

Furthermore, in this chapter, relevant current literature about smart cities was presented and reviewed. It started with focusing on smart city and smart transportation concepts in a general sense, later on, introduced the challenges and solutions for smart city analysis and benchmarking. Finally, road mapping was discussed in detail. Although many smart city roadmaps exist for other cities, hence, there is no smart city roadmap from a transportation perspective for Istanbul city and after all, the research methodology that has been used in this thesis for data collection and analysis procedures are discussed in chapter 3.

3. METHODOLOGY

The methodologies employed in the current study, as well as the research strategy used to analyze the smart city from a transportation perspective, are discussed in this chapter. In this regard, comprehensive literature reviews and bibliographic analyses are used to identify and study research. The current study employs a mix of systematic literature review and bibliographical analysis to answer the research questions in order to accomplish the research aims. Furthermore, the many procedures involved in doing a systematic literature review, as well as the reason for adopting a systematic literature review, are described in this chapter. The technique is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria, which aid in the transparent evaluation of studies, the provision of credible conclusions, and the facilitation of future research.

The literature was systematically reviewed and extracted to address the research questions set out in the introduction chapter. Systematic reviews are transparent, evidence-based methods for identifying main research contributions to a field. They vary from narrative reviews in that they follow a replicable, scientific, and transparent methodology (Tranfield et al., 2003). For systematic reviews and meta-analyses, the most commonly used guidelines are PRISMA (Moher et al., 2009). Moreover, systematic reviews enable researchers to assess the strength of published evidence while remaining as unbiased as possible. A systematic review has been claimed to be the most effective method for finding and evaluating literature, despite the fact that it can take a considerable time and requires a lot of attention to detail (Tranfield et al., 2003).

The present study follows the PRISMA 2020 Statement for conducting a systematic literature review developed through three main stages including (1) Identification of research, (2) Screening of studies, (3) Analysis, as shown in Figure 3.1. (BMJ, 2021).

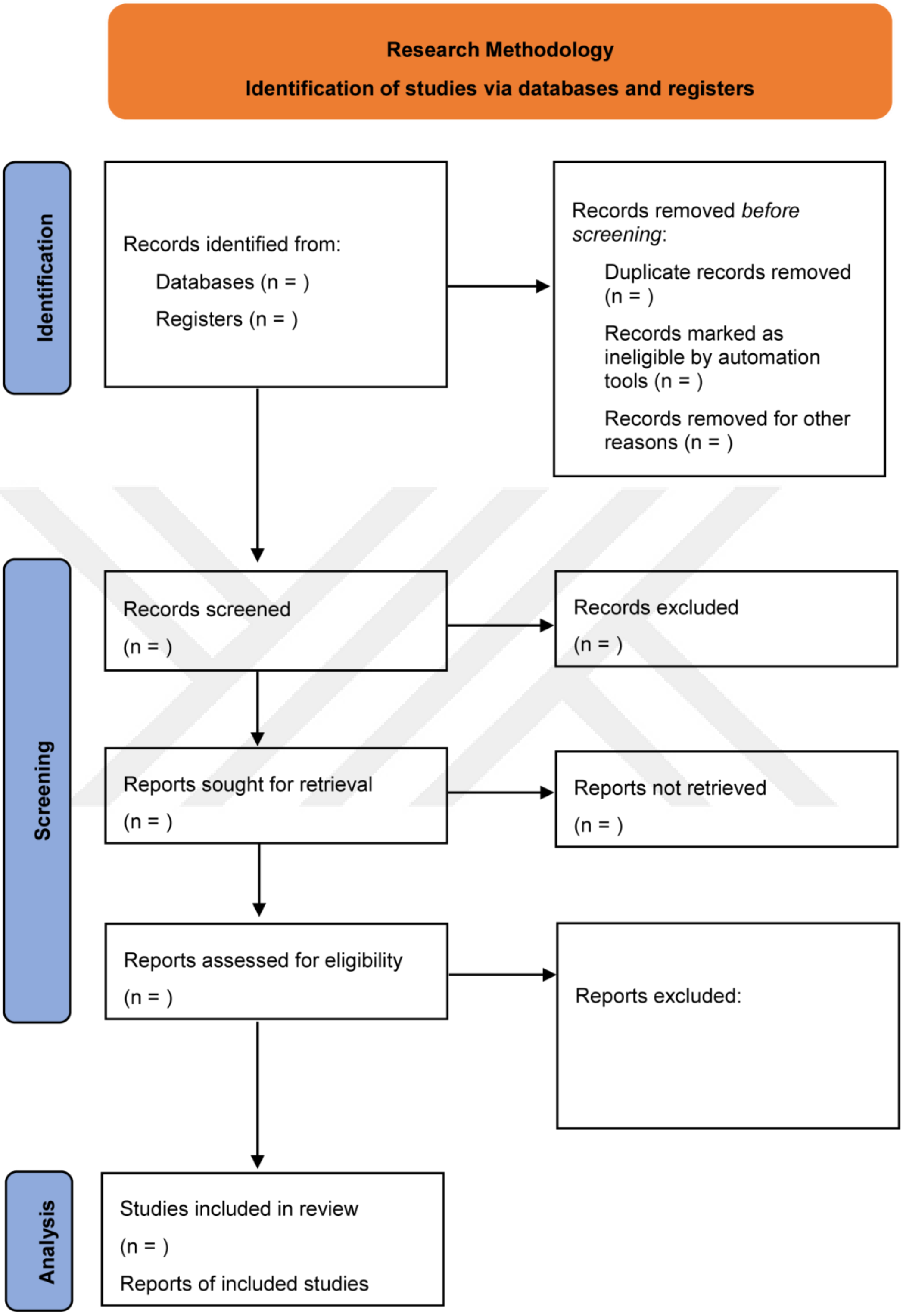

Figure 3.1: Flow chart of research methodology (PRISMA Flowchart)

3.1.Stages of the methodology

3.1.1. Phase1: Identification of research

Search strategy

In the present research, the search for articles was carried out through the Scopus database, with the initial selection criterion being articles published between 2000 and 2021. The twenty-one years' literature was examined in the present research.

For this systematic search, we developed a search strategy to identify relevant literature. The data was obtained from the Scopus database and the search terms were 'Smart city' OR 'Smart city projects' OR 'Smart city model' and these were combined with Boolean operator 'OR' which explores 'article, title, abstract keyword' of every published document in the database. All searches spanned from 2000 inception until 2021 and included journal articles published in English Only.

The first stage in our study was to find research, and in order to find literature, we confined our search to final publications published in English. Because these sources are deemed to have certified knowledge, this is a typical technique in systematic review research. (Saggese et al., 2016).

This study used the Scopus database, to search for all publications. This database was selected because of its wide and multidisciplinary scope. Using the search terms, an initial search yielded 27,431 results. Since the focus of this research was on articles, the search excluded all books, conference proceedings, journals, book chapters, citations, working papers, and reports. However, the search also had some duplication, so it was necessary to cross-check the search results from the database and delete the duplicate references. Meanwhile, the search was performed between January and March 2021.

3.1.2. Phase 2: Screening of studies

Study Selection and Selection Criteria

The selection criteria were based on the PRISMA Statement (BMJ, 2021). As the first step in screening, duplicate articles, that were common in search results, were removed before the starting of eligibility screening. The search mainly focused on mapping existing literature on smart city in the field of engineering, whilst social sciences, energy, mathematics, environmental science, material science, economics, health professions, medicine, psychology, arts & humanities, and earth science fields were excluded. The search then narrowed to the Engineering subject area.

Selected studies were read across each article to select relevant papers to include, and eligibility criteria were specified in advance to determine whether or not to exclude each identified study. On this point, studies that did not follow the inclusion criterion were excluded.

The titles and abstracts of the articles were first screened to exclude those who did not meet the eligibility criteria and were not within the scope of this study. The full text of the studies was then downloaded and closely checked to determine which should be excluded based on the eligibility criteria. As seen in Figure 3.1, PRISMA includes a flow diagram that illustrates the various stages of study selection (i.e. identification, screening and eligibility, and analysis) as well as the number of studies identified, excluded studies, and included studies in each phase.

In order to narrow down the selection of studies, we established several inclusion and exclusion criteria. The following section provides a description of the inclusion and exclusion conditions. After checking titles, keywords, and abstracts, articles that were beyond the scope of our study were excluded. The majority of papers were rejected during the selection process because they did not focus on smart cities and smart transportation. Furthermore, every paper was carefully read, and data on the research subject, methodology, and author(s) was reported on an Excel sheet.

Overall, following the elimination of duplicates, the titles and abstracts of the listed publications were scanned, and the full texts of the papers were downloaded and checked for eligibility. Overall, the articles were chosen in the following steps:

STEP 1: First, all of the titles and keywords were evaluated, and those that were clearly beyond the scope of the present study were excluded.

STEP 2: The abstracts and titles of the extracted articles were then evaluated to determine if they were relevant to;

STEP 3: After that, the abstracts of the remaining articles were evaluated using the outlined inclusion and exclusion criteria.

STEP 4: Finally, the author assessed and analyzed the full text of the retrieved articles.

Inclusion criteria

The inclusion criteria set for the selection of studies are as follows:

- Articles within the time frame of 2000-2021
- Articles in the English language
- Articles that emphasize transportation in smart city
- Articles that address smart transportation, policies, strategies with a clear focus on smart city

Exclusion criteria

The exclusion criteria set for the selection of studies are as follows:

- All articles that were not relevant to the main aim of this research and reported overviews, reports and applications that did not specifically include smart city and smart transport infrastructure were excluded.
- Articles focusing beyond and outside of the research scope
- Studies that were not in the English language
- A lack of focus on the development of the smart city and smart transportation
- Books, conference papers, citations, unfinished papers, papers under publication stage, reports, and calls for papers

Screening process

The eligibility screening process aims at ensuring that the eligibility criteria are applied consistently and unbiasedly in order to minimize the possibility of introducing errors or bias into an evidence synthesis. Articles found by searches usually include a title, an introduction, and/or a ‘full text' edition, such as an academic journal article. At these various stages of reading, eligibility screening can be used to implement a variety of filters. PRISMA recommends using at least two filters to be applied:

(i) The first reading of titles and abstracts to efficiently exclude clearly irrelevant articles; and

(ii) Assessment of the article’s full-text edition.

Eligibility (Quality assessment)

In this stage, the extracted records were evaluated and all irrelevant and duplicate articles that were not relevant to the research were excluded. Along with this study is based on research articles, duplications were carefully checked to ensure the review's accuracy and the abstracts of the papers were thoroughly checked before the articles were analyzed to ensure the accuracy, and quality of the academic literature used in the review process. At a later stage, each research paper was carefully evaluated.

3.1.3. Phase 3: Analysis

In this stage, articles were evaluated by reading the full paper, and finally, the studies were selected for the analysis.

3.1.4. Data extraction

Once all the included studies were identified in this stage, we extract and analyze the data found in those studies. In accordance with their methodologies, we created a data extraction form in Microsoft Excel for this systematic analysis.

3.2.Bibliometric evaluation

Furthermore, for analyzing the articles, this study applies bibliometric research to conducting a systematic literature review, which allows for the mapping of the intellectual structure of the smart city and smart transportation. As a result, bibliometric analyzes may assist in the comprehension of the literature.

3.3.Summary

The present chapter mostly focused on the design of the research and the different methods used in the current research. The following research justified with the systematic literature review coupled with bibliographic mapping approaches to visualize bibliometric information and findings from systematic literature review, with the research purposefully focusing on the smart city from a transportation angle.

Consequently, this chapter reported the methodology based on search strategy, selection criteria, quality assessment, and data extraction and reported by using the following search term in the SCOPUS database; *TITLE-ABS-KEY("Smart city" OR

"Smart city projects" OR "Smart city model") AND (LIMIT-TO (freetoread,"all")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"ENGI")) AND (LIMIT-TO (PUBSTAGE,"final")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SRCTYPE,"j"))*

4. IMPLEMENTATION AND RESULTS

The current study evaluated papers that were chosen following in-depth examination based on the inclusion and exclusion criteria established. As a result, the current study assessed publications that were chosen after a thorough evaluation based on the defined inclusion and exclusion criteria. As a consequence, the current study analyzed twenty-seven studies for a systematic review, using the PRISMA guidelines as the only screening strategy (Preferred Items for Systematic Reviews and Meta-Analysis).

Moreover, all of the included studies were written in English. PRISMA flow diagram is seen in Figure 4.1. displaying the selection of research for Istanbul's Smart City Roadmap.

Furthermore, the time period considered for the selection of studies for systematic review ranged from the period 2000-2021, wherein the PRISMA guidelines and flowchart are used. Around 27,431 studies were identified to have relevance to the research topic and after the classification, filtering procedure, and removing of duplicate records by Microsoft excel screened to further bring down the number to 1611. Furthermore, the criteria for filtering were set to include, the present research study smart city from the perspective of transportation for Istanbul city considers 27 studies suited that specific criterion.

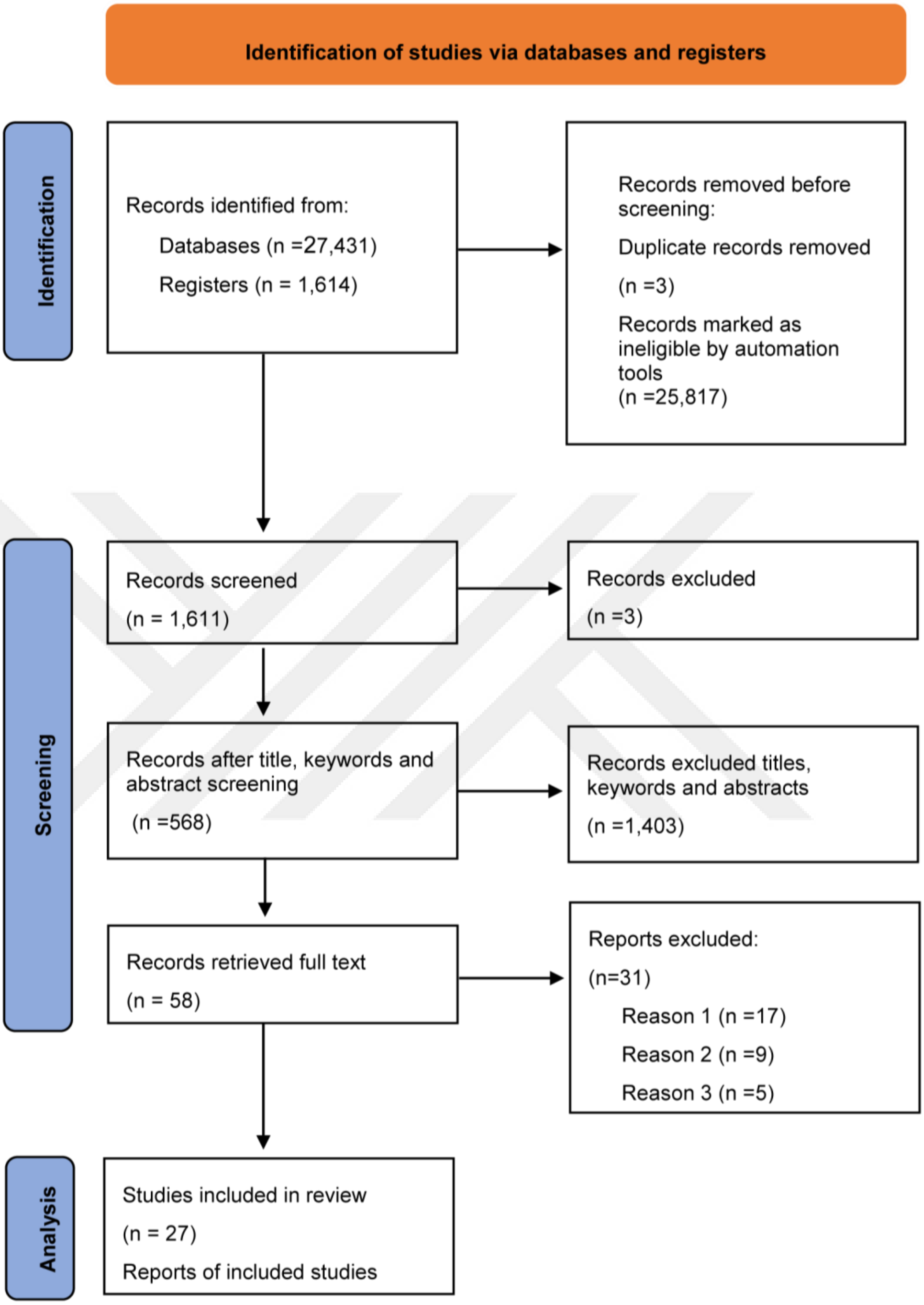

Figure 4.1: PRISMA Flowchart (PRISMA 2020 statement)

4.1.Analyzing Results

In this research firstly, through the SCOPUS database the keyword “Smart city” OR “Smart city projects” OR “Smart city model” was searched and the number of articles yielded in this stage was 27,431 results. We analyzed our results based on the following:

4.1.1. Year

Next, the search span was from the year 2000- 2021 and the spread of the reviewed articles across the years illustrates a growing trend in the articles since 2000, with a steeper increase occurring in 2019 (1656 results), 2020 (1628 results), and 2021 (55 results) onwards in screen stage, since this study only selects data’s ranging from 2000-2021, all articles before 2000 were excluded from search as which limit the study to 27,332 results. Figure 4.2 indicates the yearly trend of publications.

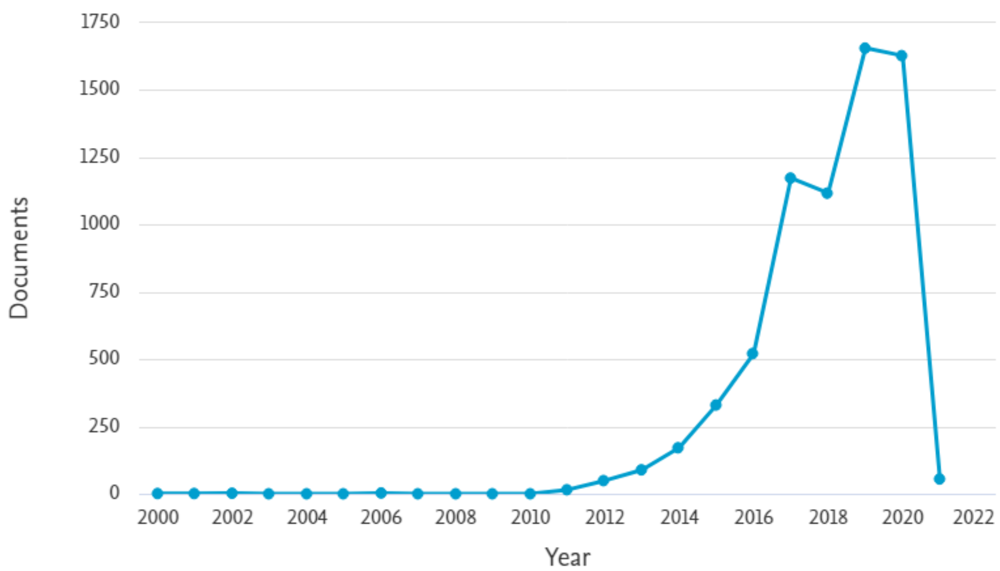

Figure 4.2: Yearly trend of publications

4.1.1. Articles by subject area

Selecting all open access journals, whereas a well-established peer review processes and maintaining high publishing standards, the results are limited to 6811. Later on in this stage, since we are concerned with engineering-related research, we categorize our research area to Engineering, as seen in Figure 4.3, limiting the study to 2,996 results.

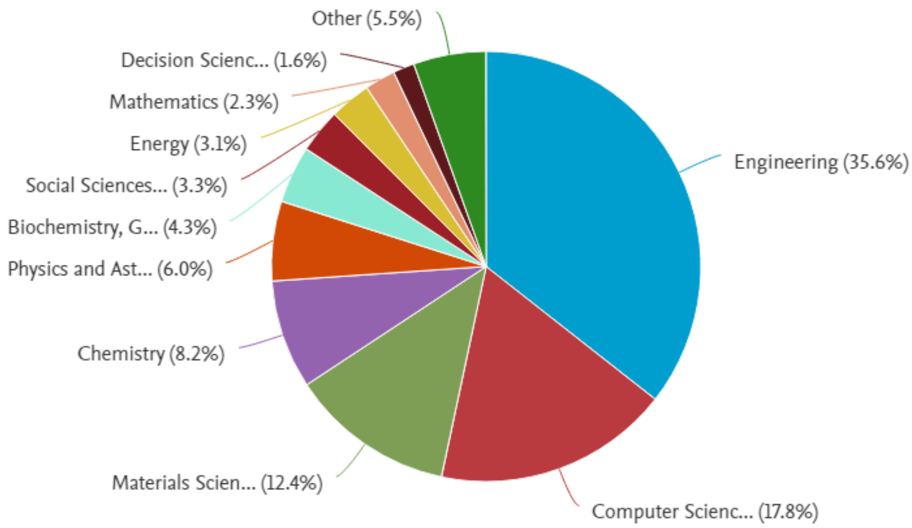

Figure 4.3: Shows results based on the Engineering perspective

4.1.2. Document by type

In this stage, only articles were chosen; conference papers, review papers, and book chapters were excluded, as seen in Figure 4.4, limiting our research to 1,655

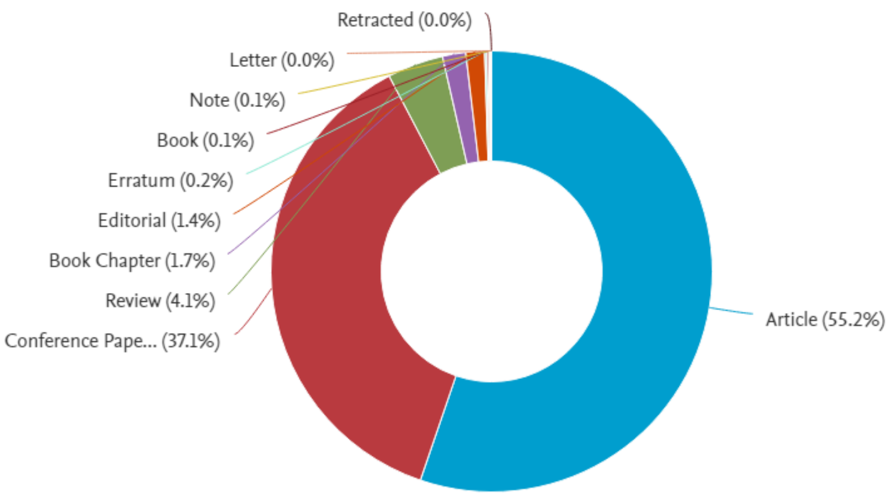

Figure 4.4: Shows the results by document type

4.1.3. Publication stage

This study only focused on final papers which limits our study to 1,628 and 27 articles in press were excluded in this stage.

4.1.4. Articles per year by source

The number of articles per year by source has been shown in Figure 4.5

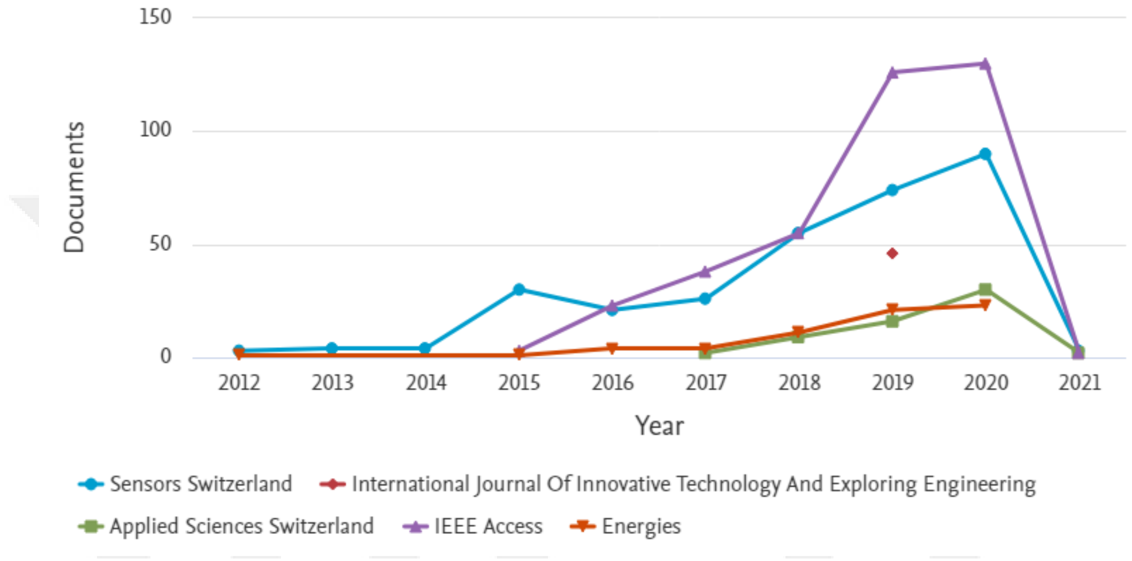

Figure 4.5: Shows the results per year by top 5 selected journals

4.1.5. Articles by author

The articles by most relevant author has been shown in Figure 4.6

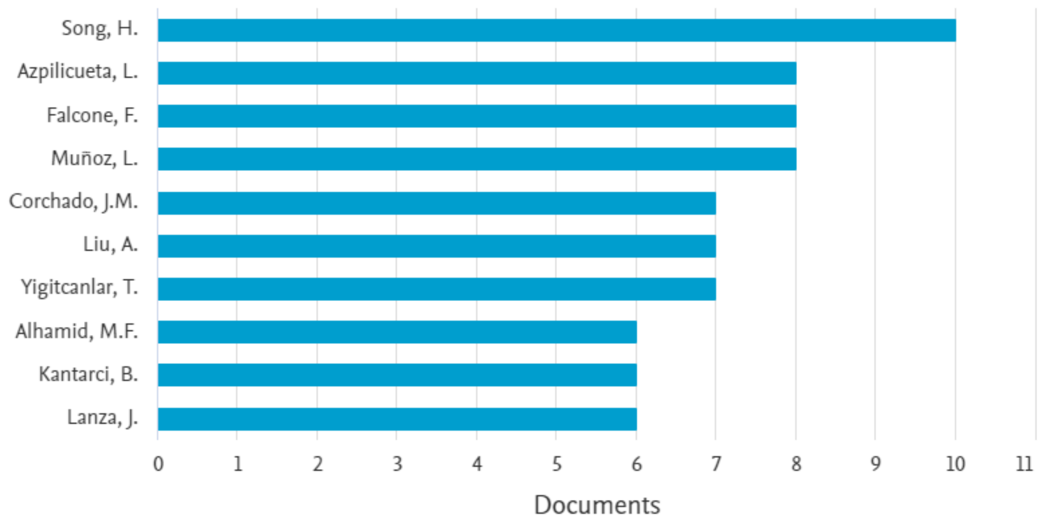

Figure 4.6: Shows the results by most relevant author

4.1.6. Articles by country

Since the search was based on countries worldwide, articles from other countries were not excluded at this stage; instead, we focused on the global as seen in Figure 4.7.a. The main search yielded 33 results for Turkey, but the results were narrowed down to 17 based on our parameters, as seen in Figure 4.7.b.

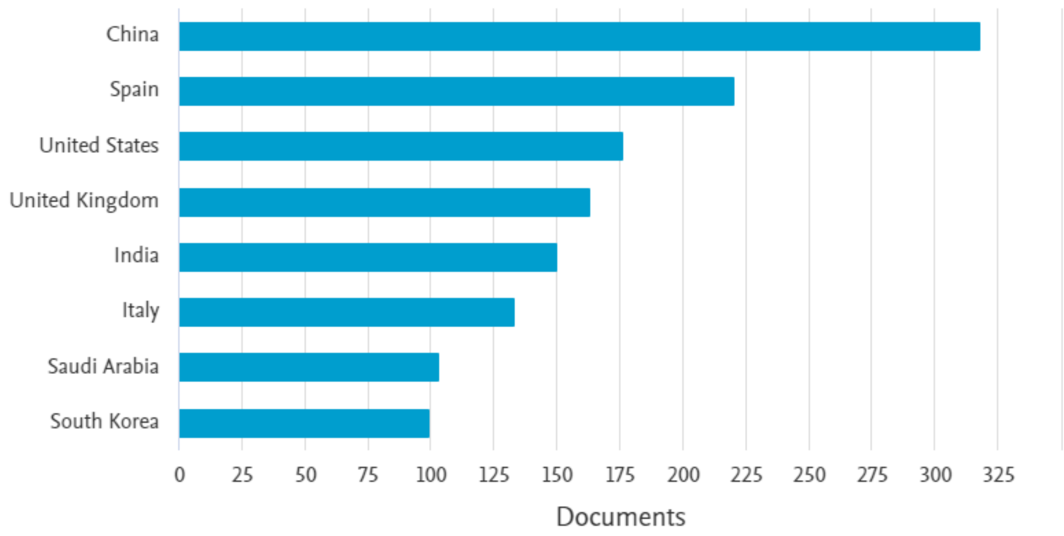

Figure 4.7 -a: Shows the results by country or territory

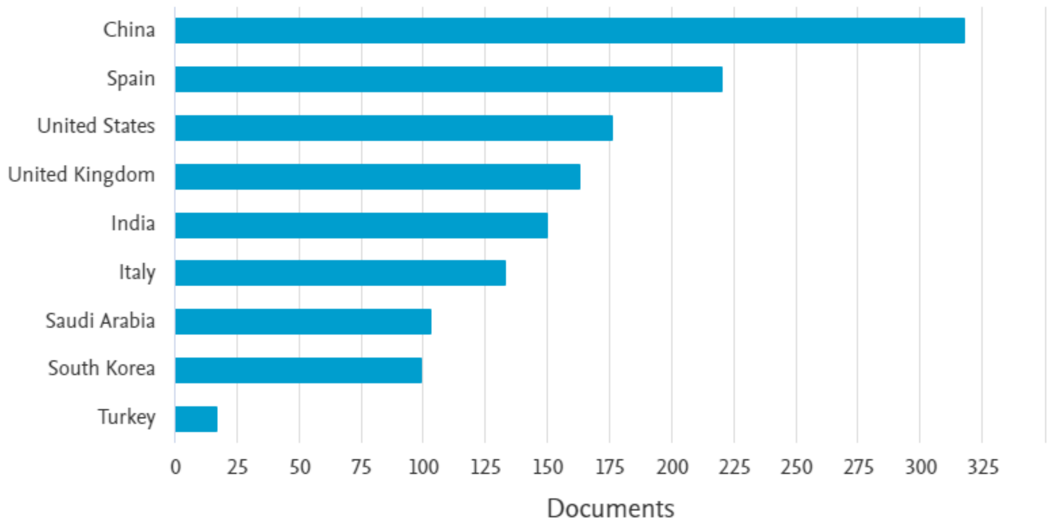

Figure 4.7-b: Shows the results by country or territory (included Turkey)

4.1.7. Source type

Only journals were selected in this stage, book series (5) trade journals (2), and conferencing proceeding (1) were excluded in this stage which limits the study to 1,620 results.

4.1.8. Language

The study was limited to 1,614 results due to the focus on English articles. At this stage, all other languages (6) results were excluded.

4.2.Bibliometric analysis

This study analyzes the articles with bibliometric analysis, in order to find out which area has been studied more and where is the gap and how different clusters with the different group has been formed. SCOPUS data are analyzed through VOSviewer software in this stage.

4.2.1. Co-occurrence

As shown in Figure 4.8, the most frequent term available in the cluster are; smart city in the red cluster, internet of things in the yellow cluster, transportation in the blue cluster, senor in the orange cluster, machine learning in the green cluster, big data in the purple cluster all interrelated with each other, where the smart city in red is the main cluster. Here we can see the distribution of the studies and knowledge within 1614 articles.

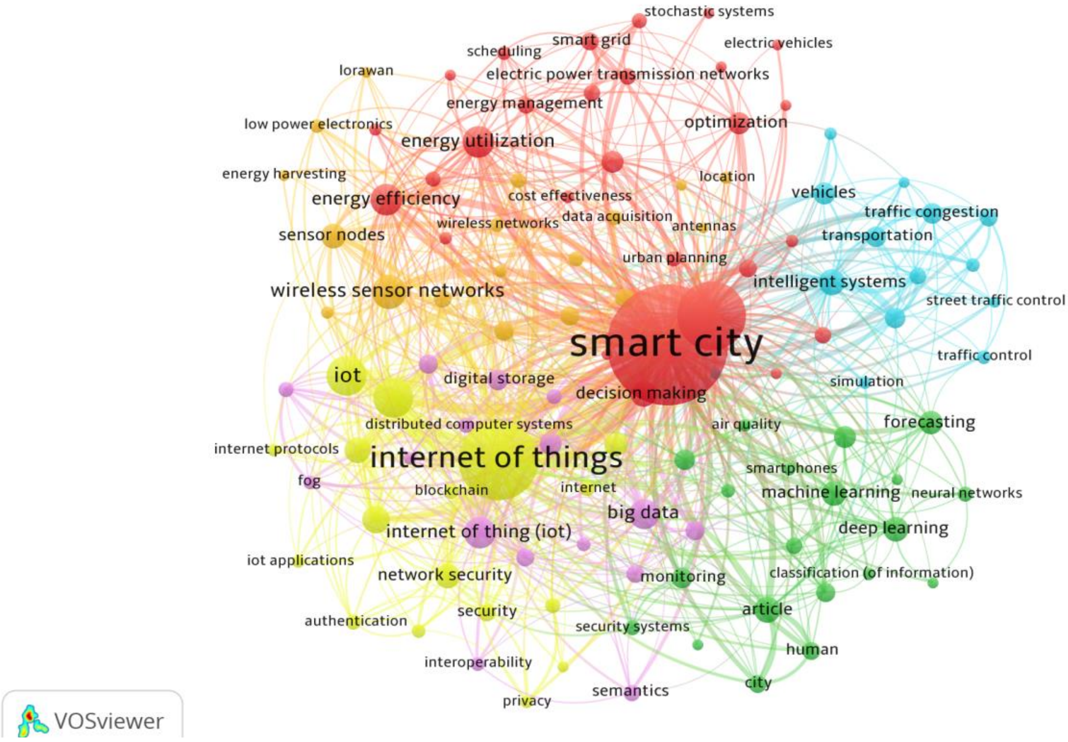

Figure 4.8: Bibliometric co-occurrence main network

Finally, the blue cluster mainly concerns “Transportation”, “Smart city”, “internet of things”, “intelligent transportation system”, “intelligent system”, “traffic congestion”, “sensor networks”, “street traffic control”, “traffic control” as shown in Figure 4.9.

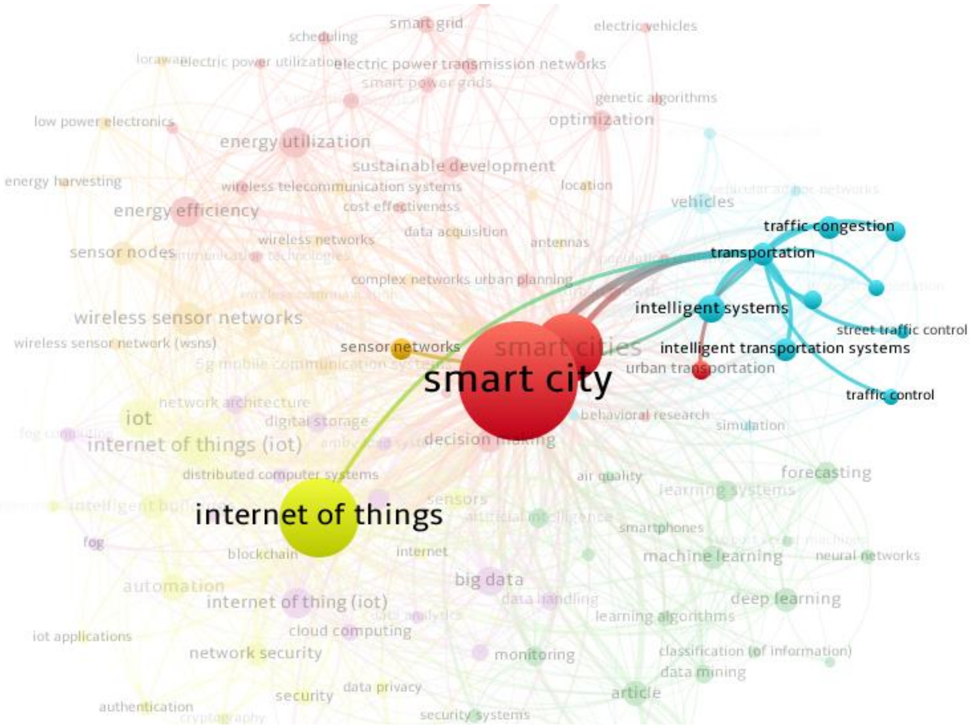

Figure 4.9: Co-occurrence transportation network

4.3.Literature review classification

1,614 articles were extracted from Scopus and moved to Microsoft excel for the selection process, in the first step duplicates were removed (3), after excluding duplicates, this study screened 1611 articles and gone under four filters, which in filter one, all of the titles and keywords were evaluated, and those that were clearly beyond the scope of the present study were excluded (1,043), then in filter two, the abstracts and titles of the extracted articles (568) were then evaluated to determine if they were relevant to and were screened to narrow down the selection process. After that, in filter three the abstracts of the remaining articles (568) were evaluated using the outlined inclusion and exclusion criteria. Recently, based on title and abstract check, in filter four retrieved full-text articles (58) were selected for eligibility, and 31 articles were excluded in this stage due to the following reasons:

Reason 1: Articles were not relevant to the topic (17)

Reason 2: Necessary data were not provided (9)

Reason 3: Insufficient data for integration of smart transportation systems (5)

Finally, after full texts of 58 studies were checked, 27 studies that met the criteria for inclusion in the review were selected as shown in Table 4.1. Furthermore, in engineering we are focused more on methods, that’s why we classified our review based on the method the researcher has used.

Table 4.1: List of included articles

No:	Authors	Title	Methods	Year	Source title	Publisher	Source
1.	Jeong S., Kim S., Kim J.	City data hub: Implementation of standard-based smart city data platform for interoperability	Experimental/Design	2020	Sensors (Switzerland)	MDPI AG	Scopus
2.	Magsino E.R.	Centralized smart parking and insurance applications for intelligent vehicles in a smart city utilizing the cloud computing paradigm	Qualitative	2020	International Journal of Advanced Trends in Computer Science and Engineering	World Academy of Research in Science and Engineering	Scopus
3.	Apanaviciene R., Vanagas A., Fokaides P.A.	Smart building integration into a smart city (SBISC): Development of a new evaluation framework	Qualitative	2020	Energies	MDPI AG	Scopus
4.	Linares M.P., Montero L., Casanovas J., Schneider B.I., Wainer G.A.	A Traffic Simulation Tool for Assessing Smart City Policies (CitScale)	Experimental/Design	2020	Computing in Science and Engineering	IEEE Computer Society	Scopus
5.	Lee W.-H., Chiu C.-Y.	Design and implementation of a smart traffic signal control system for smart city applications	Experimental/Design	2020	Sensors (Switzerland)	MDPI AG	Scopus
6.	Barletta V.S., Caivano D., Dimauro G., Nannavecchia A., Scalera M.	Managing a smart city integrated model through smart program management	Experimental/Design	2020	Applied Sciences (Switzerland)	MDPI AG	Scopus

Table 4.1: Continued

7.	Yang Y.-S., Lee S.-H., Chen G.-S., Yang C.-S., Huang Y.-M., Hou T.-W.	An Implementation of High Efficient Smart Street Light Management System for Smart City	Experimental/Design	2020	IEEE Access	Institute of Electrical and Electronics Engineers Inc.	Scopus
8.	Yun Q., Leng C.	Intelligent Control of Urban Lighting System Based on Video Image Processing Technology	Experimental/Design	2020	IEEE Access	Institute of Electrical and Electronics Engineers Inc.	Scopus
9.	Zhou L., Li Q., Tu W.	An Efficient Access Model of Massive Spatiotemporal Vehicle Trajectory Data in Smart City	Experimental/Design	2020	IEEE Access	Institute of Electrical and Electronics Engineers Inc.	Scopus
10.	Ghasemi A., Saberi M.	The key factors in transforming Birjand City to a smart city: Smart mobility, smart government	Qualitative	2020	Indonesian Journal of Electrical Engineering and Computer Science	Institute of Advanced Engineering and Science	Scopus
11.	Badii C., Bellini P., Difino A., Nesi P.	Sii-mobility: An IoT/IoE architecture to enhance smart city mobility and transportation services	Experimental/Design	2019	Sensors (Switzerland)	MDPI AG	Scopus
12.	Ochoa Guevara, N. E., Diaz, C. O., Dávila Sguerra, M., Herrera Martinez, M., Acosta Agudelo, O., Ríos Suarez, J. A., ... & López Garcia, A. C.	Towards the design and implementation of a Smart City in Bogotá, Colombia	Experimental/Design	2019	Revista Facultad de Ingenieria	Universidad de Antioquia	Scopus

Table 4.1: Continued

13.	Luo Y., Zhu X., Long J.	Data Collection through Mobile Vehicles in Edge Network of Smart City	Experimental/Design	2019	IEEE Access	Institute of Electrical and Electronics Engineers Inc.	Scopus
14.	Wang C., David B., Chalon R., Yin C.	Dynamic road lane management study. A Smart City application.	Experimental/Design	2016	Transportation Research Part E: Logistics and Transportation Review	Elsevier Ltd	Scopus
15.	Niculescu A.I., Wadhwa B., Quek E.	Smart city technologies: Design and evaluation of an intelligent driving assistant for smart parking	Experimental/Design	2016	International Journal on Advanced Science, Engineering and Information Technology	Insight Society	Scopus
16.	Asensio Á., Blanco T., Blasco R., Marco Á., Casas R.	Managing emergency situations in the smart city: The smart signal	Experimental/Design	2015	Sensors (Switzerland)	MDPI AG	Scopus
17.	Niu X., Zhu Y., Cao Q., Zhang X., Xie W., Zheng K.	An Online-Traffic-Prediction Based Route Finding Mechanism for Smart City	Experimental/Design	2015	International Journal of Distributed Sensor Networks	Hindawi Publishing Corporation	Scopus
18.	Khan S., Nazir S., García-Magariño I., Hussain A.	Deep learning-based urban big data fusion in smart cities: Towards traffic monitoring and flow-preserving fusion	Experimental/Design	2021	Computers and Electrical Engineering	Elsevier Ltd	Scopus

Table 4.1: Continued

19.	Nguyen D.D., Rohács J., Rohács D., Boros A.	Intelligent total transportation management system for future smart cities	Mixed Method (Qualitative+ Quantitative)	2020	Applied Sciences (Switzerland)	MDPI AG	Scopus
20.	Hamza M.F., Ganesh S.R., Ganesh V.S., Uddin A.A., Ghosh S.	Parking system for smart cities	Experimental/Design	2019	International Journal of Recent Technology and Engineering	Blue Eyes Intelligence Engineering and Sciences Publication	Scopus
21.	Ho G.T.S., Tsang Y.P., Wu C.H., Wong W.H., Choy K.L.	A computer vision-based roadside occupation surveillance system for intelligent transport in smart cities	Experimental/Design	2019	Sensors (Switzerland)	MDPI AG	Scopus
22.	Bıyık, C.	Smart cities in Turkey: Approaches, advances and applications with greater consideration for future urban transport development	Qualitative	2019	Energies	MDPI AG	Scopus
23.	Zaheer T., Malik A.W., Rahman A.U., Zahir A., Fraz M.M.	A vehicular network–based intelligent transport system for smart cities	Mixed Method (Qualitative+ Quantitative)	2019	International Journal of Distributed Sensor Networks	SAGE Publications Ltd	Scopus

Table 4.1: Continued

24.	**Ding H., Li X., Cai Y., Lorenzo B., Fang Y.**	**Intelligent data transportation in smart cities: A spectrum-aware approach**	**Quantitative**	**2018**	**IEEE/ACM Transactions on Networking**	**Institute of Electrical and Electronics Engineers Inc.**	**Scopus**
25.	Ramos F., Trilles S., Muñoz A., Huerta J.	Promoting pollution-free routes in smart cities using air quality sensor networks	Qualitative	2018	Sensors (Switzerland)	MDPI AG	Scopus
26.	Lücken V., Voss N., Schreier J., Baag T., Gehring M., Raschen M., Lanius C., Leupers R., Ascheid G.	Density-Based Statistical Clustering: Enabling Sidefire Ultrasonic Traffic Sensing in Smart Cities	Mixed Method (Qualitative+ Quantitative)	2018	Journal of Advanced Transportation	Hindawi Limited	Scopus
27.	Zhang Y., Zhang G., Fierro R., Yang Y.	Force-Driven Traffic Simulation for a Future Connected Autonomous Vehicle-Enabled Smart Transportation System	Experimental/Design	2018	IEEE Transactions on Intelligent Transportation Systems	Institute of Electrical and Electronics Engineers Inc.	Scopus

4.4.Results and discussions

This group of papers is divided into two subcategories of smart city and smart transportation. The first subset introduces a conceptual approach to smart cities and smart transportation and the reasons that cause traffic jams. For example, Barletta, et al., has done experimental research and investigate that the conceptual approach to a smart city includes six dimensions; smart economy, smart government, smart transportation/mobility, smart environment, smart people, and smart living which plays a key role in the development of a smart city strategy (Barletta, et al., 2020). Correspondingly, Apanaviciene et al. (2020), have done qualitative research and choose domains after a review of various current classifications and consideration of the major interconnectivity dimensions of smart building and smart city digital networks. Table 4.2 contains an overview of each domain.

Table 4.2: Integration of smart city described by smart city domains. (Apanaviciene et al., 2020)

Smart City Domain	Description
Smart Transportation/mobility	Obtaining authentic information about the mobility and demands of participants in the immediate vicinity. Linkage to networks allows for more effective supplies & infrastructure, while also taking into account prior issues and fixing them in line with realistic trends and growth objectives.
Smart Environment	External environment observation, analysis, and adaptation, as well as the capacity to acquire information from significant players and institutions. Comparison and management of renewable resources, reusable materials, waste, and justification for actions derived from past / earlier reports are all available online.
Smart Energy	When linked to the networks, the reaction to real-time power changes. Gathering data, analyzing it, comparing it to prior events, and recalling it to support decision-making and control in order to get the best results.

Table 4.2: Continued

Smart Data	Analysis, comparison, and justification of obtained data. Reporting and disseminating aggregated data to multiple players in charge of remote control.
Smart Life	Automatic or online disaster prediction, safety, health, comfort, and quality assurance, with the capacity to save, analyze, compare data, and make educated decisions.

Similarly, Barlletta, et al. (2020), envisioned a smart city built on a two-dimensional interconnected model of horizontal and vertical dimensions. A series of four overlapping technical layers are represented by the horizontal dimensions and six domains are represented by the vertical dimensions as shown in Figure 4.10.

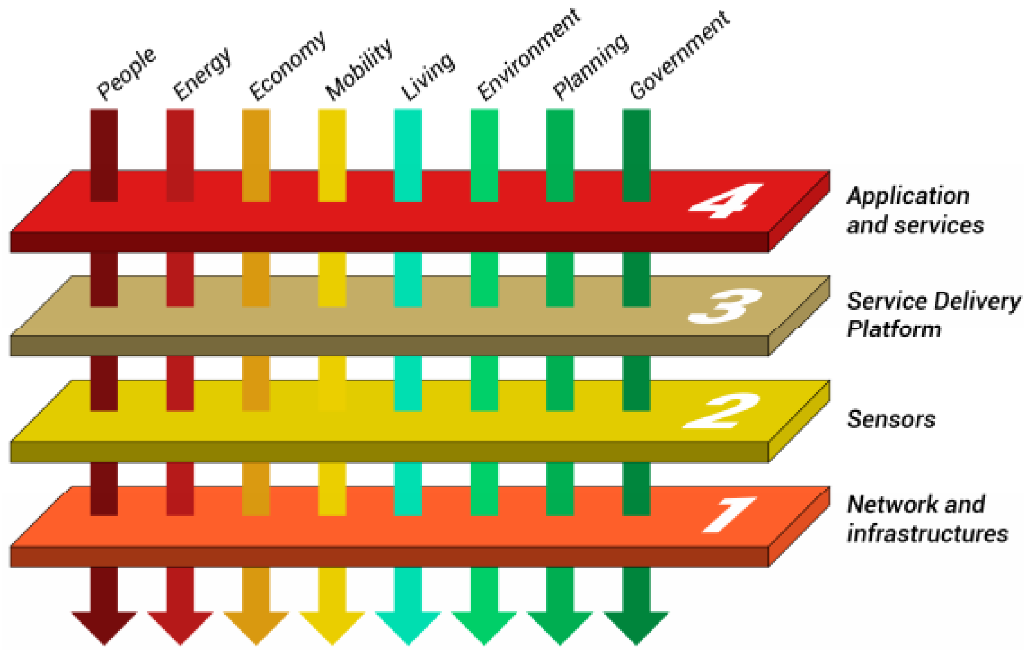

Figure 4.10: Interaction between application domains and technological layers. (Barletta et al., 2020)

Accordingly, Ghasemi and Saberi (2020), in their qualitative study linked the six domains with transportation and presents the policies and regulations that regulate the implementation of e-government and intelligent transportation systems (ITS), as they encompass the six suggested dimensions: smart economy, smart citizen, smart government, smart transportation, smart environment, and smart living. Similarly, Lee et al. (2020), investigate that intelligent transportation systems (ITS) should be developed for reducing traffic congestion and improving public transport efficiency and also proposed a multi-modal smart traffic control system (STSC) for smart city networks, which can be commonly used in smart city implementations for intelligent transportation systems.

In another study, Nguyen et al. (2020), have done a mixed qualitative and quantitative study and highlights that important elements of the smart cities are smart transportation and smart mobility. According to the authors' reduced travel times, on-time arrival, fuel consumption, and congestion, as well as improved road safety, are all goals of a smart transportation system, or intelligent transportation system (ITS) and also stated that the Internet of Things (IoT) is used in a variety of smart transportation system implementations, including smart roads, intelligent parking systems, and data of real-world connected vehicles.

Magsino (2020), has surveyed the possible deployment of cloud-computing applications and found that a centralized smart parking system is feasible and rely on ITS and highlights that one of the reasons for traffic congestion is finding a suitable parking space which is time-consuming and also an important aspect of traveling in a city as there are a small number of these parking lots in most cities, and they are filled on a first-come, first-served basis. According to the author, ITS is used to achieve transportation goals including shorter travel times, more efficient travel routes, and fast emergency response. Correspondingly, for reducing emissions and traffic congestions, Linares et al. (2019), investigate that an important part of traffic planning which is a sustainable transport system will reduce emissions and congestion. Similarly, Ocha, et al. (2019), highlighted that improvement of public transportation and increase in pedestrsianization will reduce car emissions. Accordingly, Niculescu, et al. (2016), develop traffic management systems and smart parking applications with the purpose of monitoring and directing drivers toward free parking places. Another factor that causes traffic congestions stated by Ho et al. (2019), is that in cities with high transportation density double parking and roadside operations like truck loading and unloading have a negative effect on traffic as shown in Figure 4.12.

Idle lane for public transport

Double parking in the roadside, due to (i) logistics trucks for loading and unloading, (ii) company private cars, and (iii) obstacles

Figure 4.11: Roadside example of double parking. (Ho, et al., 2019).

The second subset of articles includes strategies, policies, and proposes for smart city and smart transportation as well solutions overcome traffic congestion. Many smart city solutions according to Niculescu, et al. (2016) are focused on designing intelligent transportation systems (ITS) to promote city growth. Moreover, a similar conclusion is reached by Lee et al. (2020), that ITS should be developed for reducing traffic congestion and improving public transport efficiency.

Niculescu, et al. (2016), present the ITS strategies for cities in order to become more clean, safe living places and sustainable places, for example for solving the problem of air pollution; bike rental/sharing schemes, electric vehicles, self-driving cars, and on-demand taxi/buses should be promoted while, other policies encourage people to use public transportation by implementing reliable travel management systems, ticketing, and mobile payments and also considerable effort should be put into developing smart strategies for traffic planning.

Traffic jams and a lack of parking spaces are two of the most important problems that modern cities are facing. According to traffic analysts, 30 percent of drivers in big cities' urban areas are searching for a parking spot, and they spend an average of 7.8 minutes to find one. This searching process increases traffic while also wastes time, fuel costs, and CO2 emissions (Niculescu et al. 2016). Moreover, a similar pattern of results was obtained by Hamza, et al. (2019) that 66 percent of the public in peak hours of holidays and weekends spend an average of 10 minutes to find a parking lot which can cause traffic jams may lead to security issues and expounded a solution by using sensors and IoT. As a result of this challenge, Niculescu, et al. (2016) develop smart city strategies with a variety of smart parking systems aimed at reducing traffic and making parking more accessible and classified Smart parking systems into five divisions based on their functionality; Park guidance information (PGI) systems, Transit-based smart parking, smart payment systems, E-parking systems, Automated parking system.

Linares et al. (2019), investigates that an efficient way to reduce the number of private vehicles on a road network from the perspective of sustainable urban mobility it's the shared journey or ridesharing modality as a mode of transport that singles travelers share a vehicle which reduces congestion, environmental impacts, and energy consumption while increasing service efficiency. Moreover, Nguyen et al. 2020), Incorporate urban air transportation, such as air taxis and drones, into total transportation or total transportation systems. Future and developing technologies, according to the author, that enable the creation of smart city solutions, particularly smart city overall transportation management, include:

- New transportation network optimization, new (lightweight) materials (such as entirely composite cars), new solutions (such as electric vehicles), new non-traditional solutions (such as autonomous vehicles, pilotless taxi drones);
- New information and communication technology based on wireless technology, the internet, the cloud, and the notion of the Internet of Things;
- Sensors and actuators, based on micro-electric-mechanical-systems (MEMS) for traffic monitoring and active control;
- Using soft computing and artificial intelligence, further data processing, situational awareness - evaluation - decision-making is possible (Nguyen et al, 2020).

Moreover, Ho et al. (2019), suggested wireless high-definition smart cameras communication for traffic surveillance as a solution for the problem of double parking and roadside that causes traffic congestions from Hong Kong, Kwun Tong district case, and Ochoa et al. (2019), emphasized on the usage of the bicycle as an alternative mean of transport in smart parking cycle. In addition, Zaheer et al. (2019) present a smart city framework that allows for ad hoc route selection based on real-time data received from nearby vehicles by using directly enabled android smartphones in vehicles and when compared to a traditional fixed route-selection algorithm, the final results indicate a 33.3 percent reduction in travel time. In line with previous studies, Niu et al. (2015), proposes O-sense, an innovative online traffic prediction that helps to find the fastest route based on online route computing and route-finding mechanism which uses a large taxi GPS traces and environmental information and for evaluation of the approach the author generated datasets in Wuhan city by 30,000 taxis in three months and the final investigation made by the author showed that O-sense will help you increase the precision of your travel cost estimates. Furthermore, as shown in Table 4.3, Bayık (2019) conducted a qualitative study for Turkey's urban areas and proposes three visions (walking, public transportation, and cycling) for 2035 to bring about changes in transportation systems.

Table 4.3: Turkey’s 2035 visions for urban area (Bıyık, 2019)

	Shift Vision	**Improve Vision**	**Avoid Vision**
Technological innovations	Developing apps that encourage people to walk and cycle	In traffic, there will be less traffic and public transportation cars that are less polluting.	Improvements to reduce the risk of traffic accidents among various users
Environmental solutions	Car-free zones in metropolitan areas are being established.	Public transportation systems for all commuters have been greatly extended.	In urban areas, reducing the necessity for vehicle travel
Mode-sharing arrangements	Walking is 45 percent, cycling is 10%, public transportation is 35%, and driving is 10%.	Walking is 40% of the time; cycling is 5% of the time; public transportation is 50% of the time; and driving is 5% of the time.	Walking is 40% of the time; cycling is 5% of the time; public transportation is 35% of the time; and driving is 20% of the time.
Land usage and urban form change	Urban shape that is more compact and mixed-use. Changes in urban form are usually gradual.	Rapid population expansion is expanding to the outskirts of cities, resulting in the formation of new parks and woods.	The cost of living in the city core is high. Increasing the elevation would make it more difficult to create compact cities.

According to the author, designing more sustainable transportation systems using energy and technological approaches has become more difficult and unpredictable as the urban population and vehicle ownership in Turkey cities has increased.

Based on an analysis of the literature, it’s worth mentioning that smart transportation is a major dimension of smart city growth around the globe and smart transportation is one dimension of smart cities, and it leads to several other components and dimensions that make up a smart city. Smart transportation is improving the traffic flow and make communities more safe and livable. The key goal of both smart transportation and smart cities is to make life easier for residence, especially in terms of reducing traffic jams which lead to carbon emissions and air pollutions. According to the studies, energy is still a priority in all smart transportation strategies, while on the other hand, smart transportation is more than just resources and technology; it encompasses a variety of applications, advancements, and techniques that help to shape the idea of future urban planning and smart cities. According to the author, designing more sustainable transportation systems using energy and technological approaches has become more difficult and unpredictable as the urban population and vehicle ownership in Turkey cities has increased.

4.4.1. Implications

The development of a Smart transportation system provides urban mobility solutions for the residence and can be accomplished by the most widely adopted methods for dealing with the challenges of current urban transport systems. Istanbul city, on the other hand, to improve the transportation systems and reduce traffic congestion, will first reduce private car usage by a greater proportion of pull (e.g., the introduction of cycling into the transportation system, improved metro, ITS, and construction of light rail systems). In line with Bıyık (2019), as Figures between 4.12-4.20 indicates, based on the following 9 key factors this study proposes the top elements on the design of the transportation system for Istanbul city as shown in Figure 4.21.

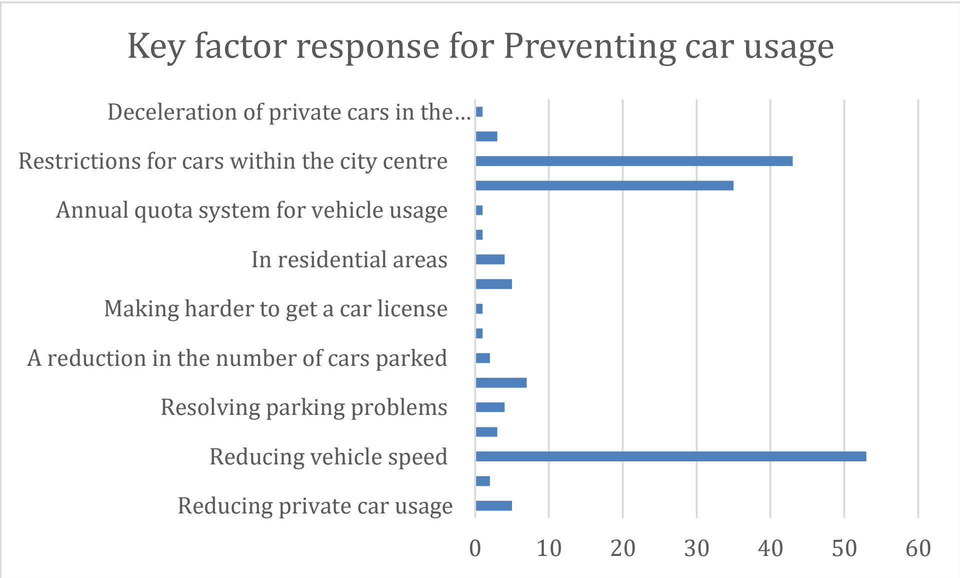

Figure 4.12: Key factor response for Preventing car usage (Bıyık, 2019).

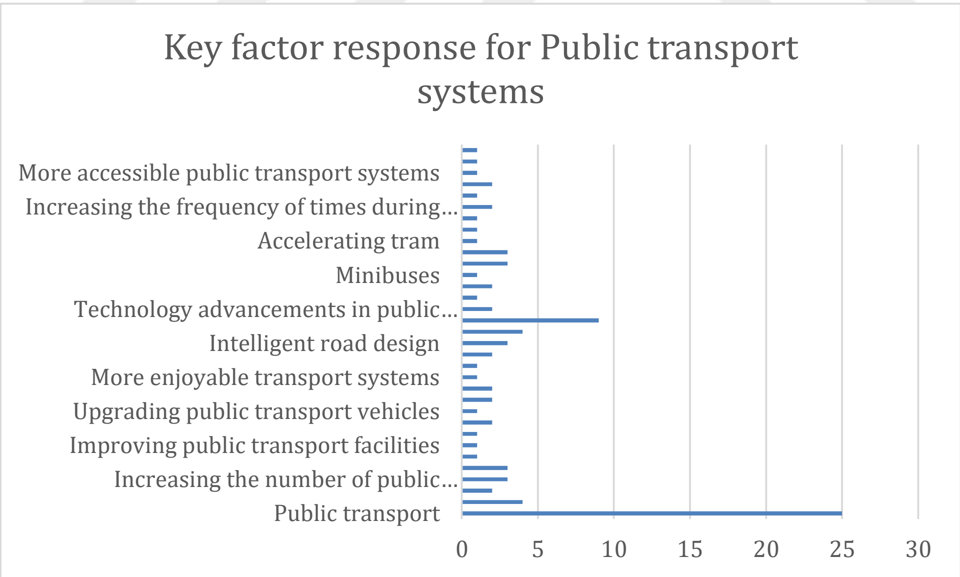

Figure 4.13: Key factor response for Public transport systems (Bıyık, 2019)

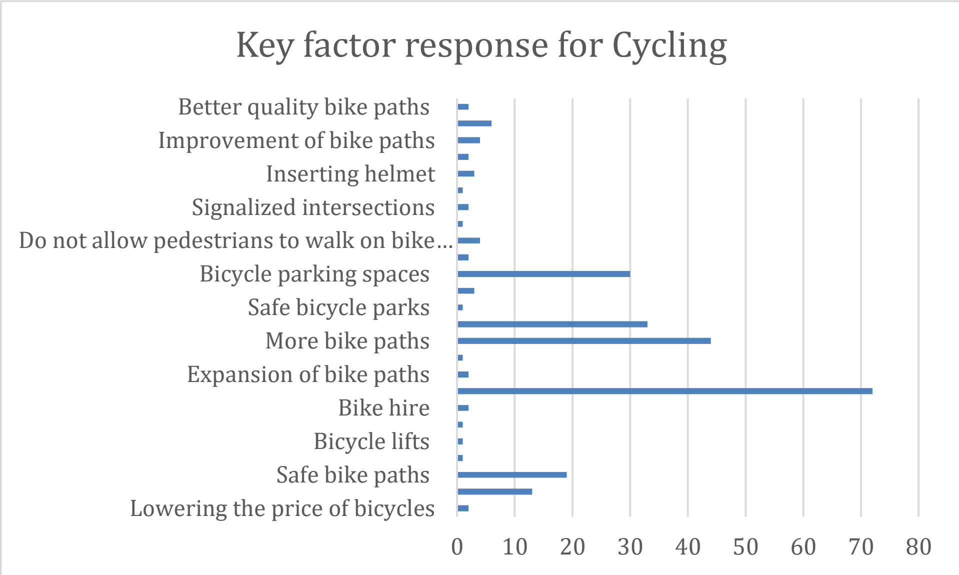

Figure 4.14: Key factor response for Cycling (Bıyık, 2019)

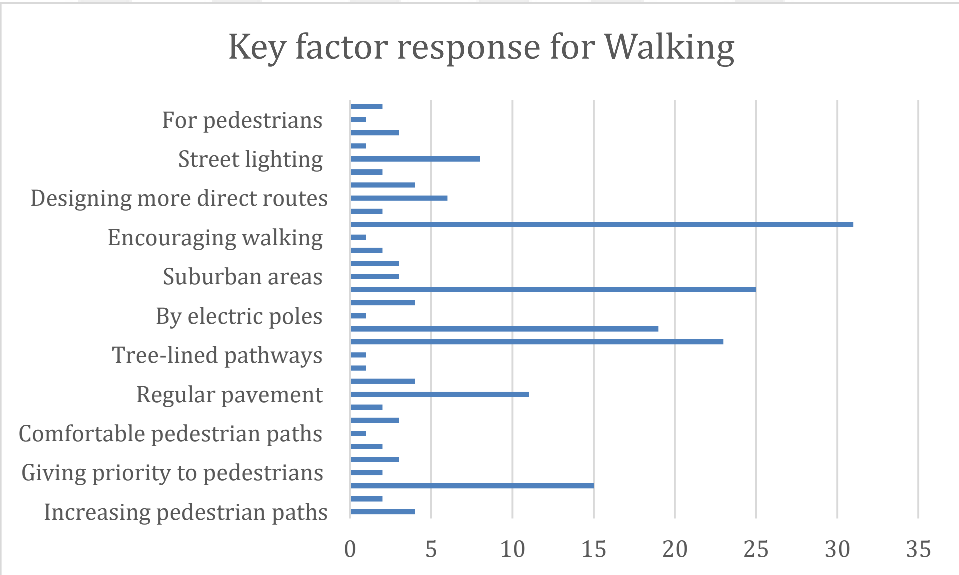

Figure 4.15: Key factor response for Walking (Bıyık, 2019)

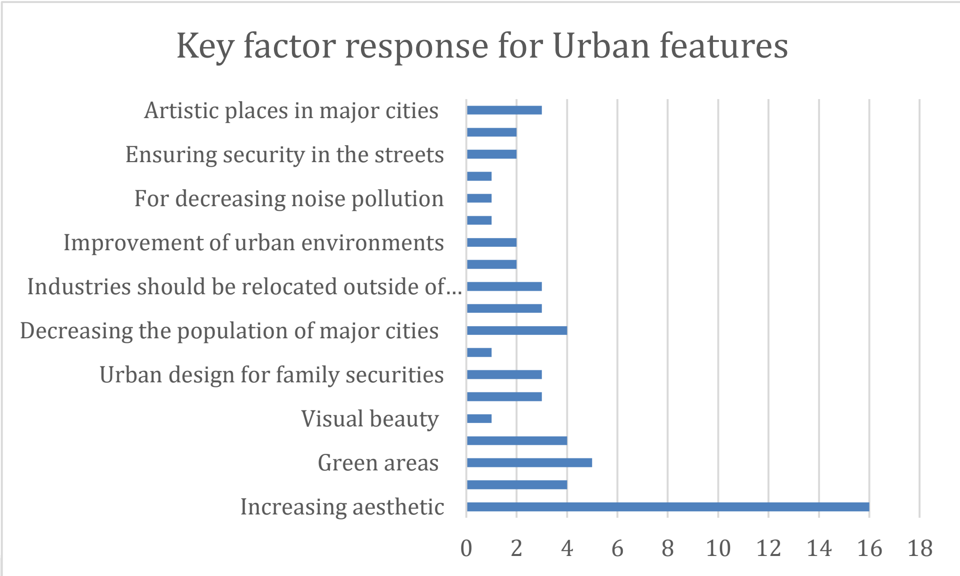

Figure 4.16: Key factor response for Urban features (Bıyık, 2019)

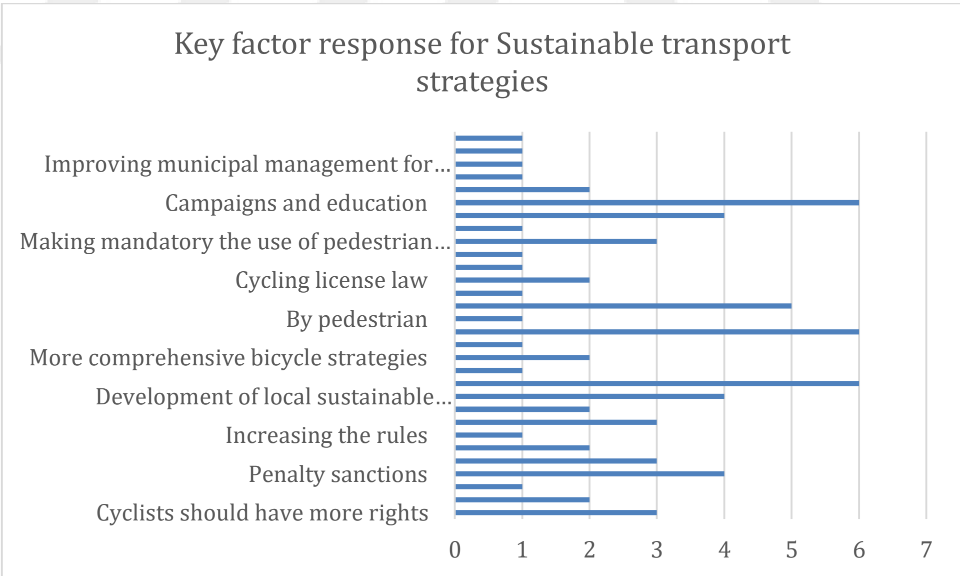

Figure 4.17: Key factor response for Sustainable transport strategies (Bıyık, 2019)

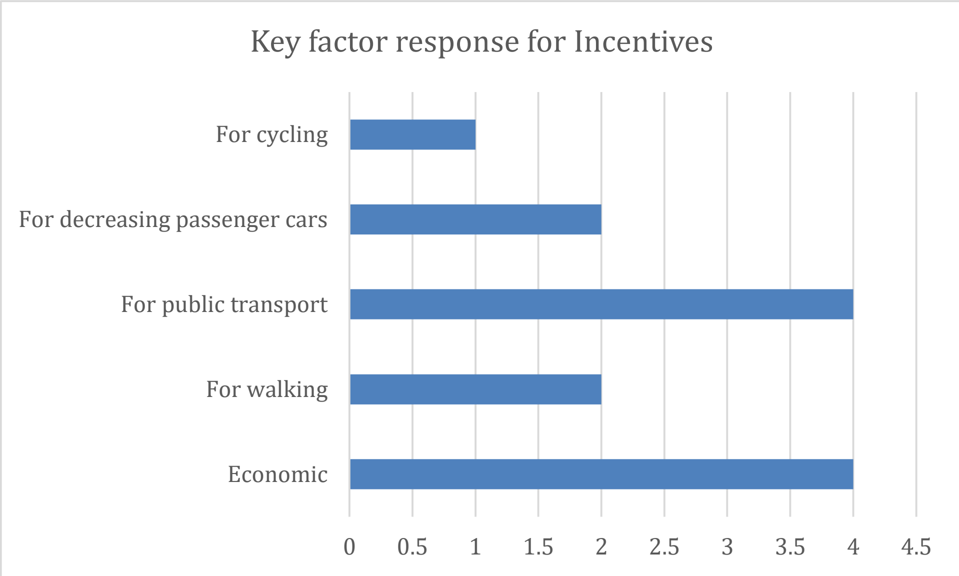

Figure 4.18: Key factor response for Incentives (Bıyık, 2019)

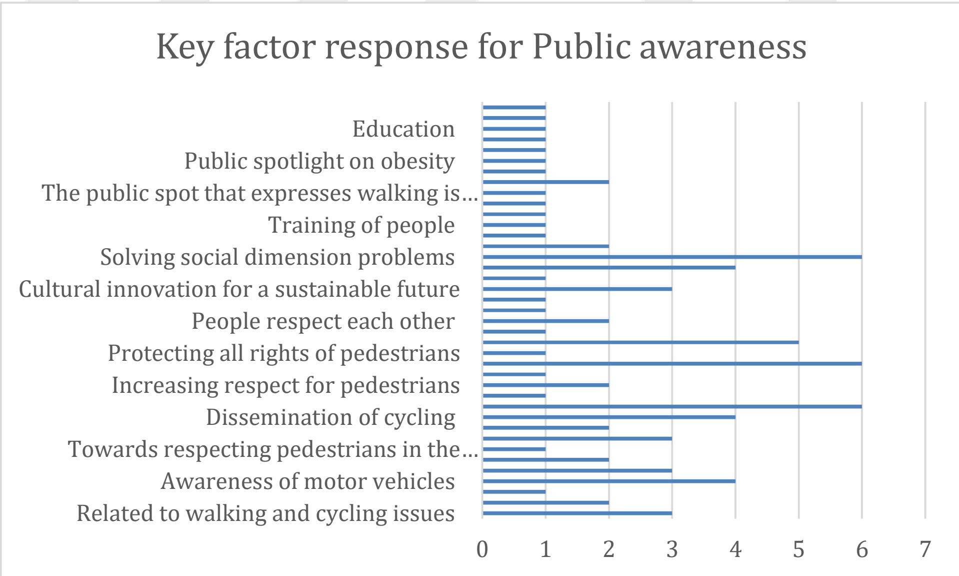

Figure 4.19: Key factor response for Public awareness (Bıyık, 2019)

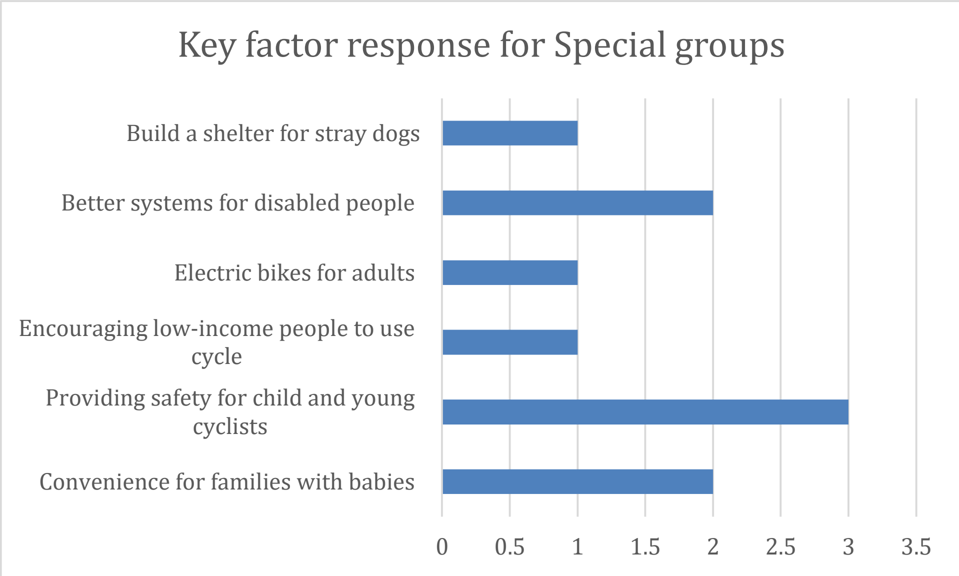

Figure 4.20: Key factor response for Special groups (Bıyık, 2019)

Finally, from the stated recommended key factors here this study presents the top elements for the Istanbul transportation system as shown in Figure 4.21.

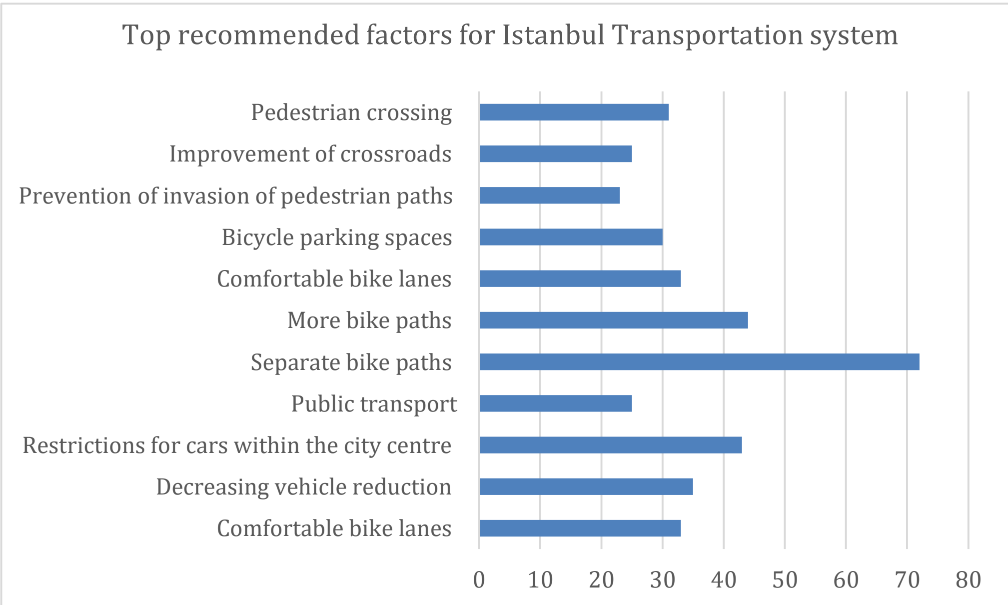

Figure 4.21: Top recommended elements for Istanbul Transportation system

4.4.2. Roadmap

Finally, this research created the following roadmap after analyzing and evaluating the bibliometric and systematic review as seen in Figure 4.22. This roadmap has four sections. The first part is the obtained data from the bibliometric analysis that mainly concerns (smart city, ITS or Smart transportation, traffic congestion, and sensors) while the rest parts are related to the results of the systematic review. The first section is related to Smart city clusters, the second section is related to Challenges (Traffic congestion, environmental impact or pollution, collisions & accidents, vehicle ownership, payrolls and maintenance, double parking, lack of parking space which lead to; increase in traffic, time-consuming, fuel cost, and CO2 emissions), the third section is related to Implementation and developments; Smart parking systems (PGI (Parking guidance information), transit-based smart parking, e-parking's, automated parking systems), smart cycling, public transportation utilization, rideshare, O-sense, smart roads, connected vehicles and the last section of the roadmap concerns future emerging technologies like; Air transport, air taxis, air drones, MEMS, Electrical cars and full composite vehicles.

This roadmap introduces various transport modes as a solution for the challenges that smart cities are facing nowadays including, Smart parking's, Public transportation utilization, Rideshare, High definition cameras, and O-sense technology.

Smart parking sub-solutions concerns the following development;

- Park guidance information (PGI) systems: this technology is excellent for minimizing traffic and decreasing the time spent looking for a parking spot by directing cars to available parking lots.
- Transit-based smart parking is a similar technology to PGI. The primary goal of transit-based parking is to allow drivers to leave their cars at train stations and use public transportation instead. The advantage of such a system will reduce drivers' transportation costs as well as congestion and environmental pollution, while still raising revenue for public transportation agencies. BART, a transit-based smart parking initiative in the San Francisco Bay Area, is an example of this category.

- E-parking systems offer drivers the option of using online systems to reserve space at a certain location by downloading the application is downloaded or paying for rides directly on the service's website.
- Automated Parking system: This is a complex system that allows drivers to leave their vehicle in a bay and have it parked remotely by a computer device. Automatic parking is particularly useful in congested areas because it maximizes space usage, reduces the chance of collisions accidents that often occur while parking, and ensures the safety of vehicles by eliminating the need to access the parking lot.
- Smart Payment Systems and smart parking systems should be integrated to save costs by lowering maintenance and payroll costs.
- Smart Cycling (bicycles): can be used as an alternative means of transport in a smart parking cycle. However, such a system has challenges such as identification, theft, storage, and organization while according to the findings of systematic reviews this roadmap suggests the usage of biometric fingerprint equipment as a solution for this problem.

Moreover, based on the results from systematic review this roadmap suggests public transport utilization for the challenge of vehicle ownership or increase in number of vehicles, and ridesharing or shared journey modality as a solution for reducing congestion. However, such a solution would have challenges like coordinating and timing in a systematic way that should take into account the user interests and requirements for future. A practical example of this project is in KUTSUPLUS project in Helsinki that offers uninterrupted trips without the hassle of parking. Furthermore, O-sense, an innovative online traffic prediction can be used to helps to find the fastest route based on online route computing and route finding mechanism that will help to reduce the travel costs.

At the last section, this roadmap introduces future emerging technologies as a new form of transport to enable the development of smart city solutions especially smart transportation total management in future, such as Air transport (air taxis and drones), autonomous vehicles, new lightweight materials as full composite vehicles, electric vehicles, MEMS (micro-electric-mechanical-system) enabling traffic monitoring and active control based on sensors, IoT and further data processing, situation awareness–evaluation–decision making by the methods of soft computing and artificial intelligence. These emerging technologies have a great efficiency for traffic congested cities like Istanbul.

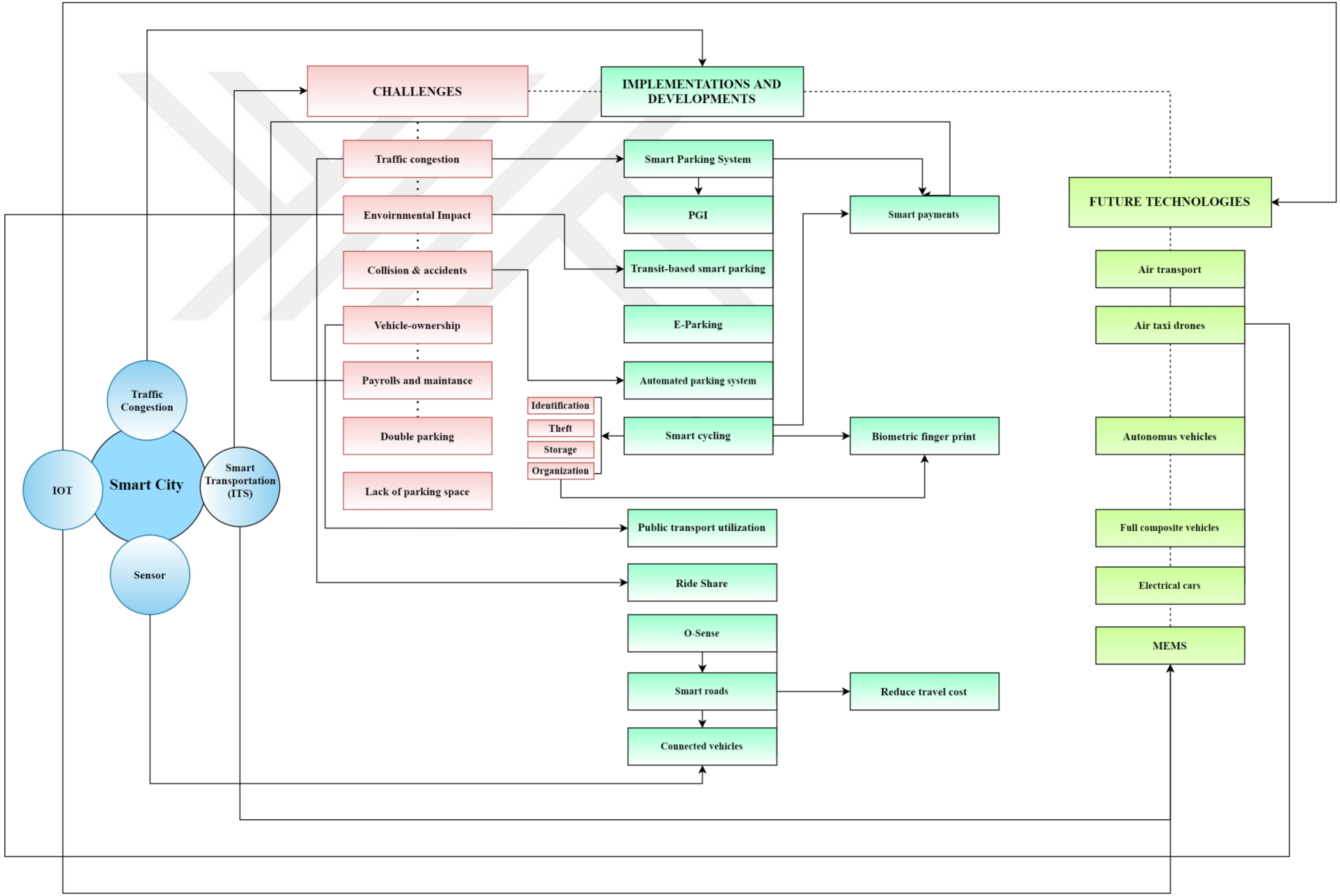

Figure 4.22: Proposed Roadmap

This research outlined a systematic review and bibliometric analysis of smart cities for Istanbul from the perspective of transportation, which would result in decreasing traffic congestion problem in Istanbul city, in achieving the development of smart transportation systems. The main finding from this study is that Istanbul city should follow implemented projects in other smart cities, switching to more active forms of transport is feasible and residence should use public transportations to eliminate their dependency on cars usages. Furthermore, this study's findings suggest that intelligent transportation systems (ITS), smart parking systems, and encouraging residents to use public transportation will help to reduce traffic congestion, air pollution, vehicle emissions, and improve transportation quality. Several various concepts, such as mode of transit, ridesharing, and vehicle sharing, smart cycling, sensors, and connected vehicle technologies should be developed and applied to reduce traffic congestion.

Finally, the findings of this research reveals that smart transportation will result in reduced traffic congestion, a better environment, safer cities, lower costs, better ways to overcome traffic congestion issues, and the replacement of traditional transportation methods with future emerging technologies. However, to reach these goals a wide-ranging approach must be integrated among a number of different public and private sectors. Such an approach may be idealistic, municipalities, on the other hand, should take a structured approach and policies to design a practical and flexible smart city infrastructure in order to reap these goals and benefits.

4.4.3. Future recommendations

Based on the data obtained from the roadmap this study recommends the following short-term, mid-term, long-term future developments in order to be prepared to face transportation problems in the future:

Short-term developments

- Transportation developments including accessible smart parking systems
- Use smart payments and developing an application for parking lots
- Developments to prevent traffic collisions & accidents
- Reduce private vehicles usage by encouraging people to use public transportation with economical and accessible offers

- Use sensor technologies, IoT, and digital apps to offer residence better and updated real-time travel information

Mid-term developments

- Encouraging businesses to work remotely
- Developing applications for smart cycling and walking
- Developing and offers services for public transportation including; rideshare

Long-term Developments

- Adding electrical cars and full composite vehicles to reduce environmental impact
- New emerging technologies including;
- Air Taxi drones: Air taxi drones are a feasible mode of transportation for reducing traffic congestion. It's a pilotless taxi that can land anywhere in the city, allowing people to get to their destination even more quickly. This will not only shorten travel times, but will also reduce traffic jams and put less pressure on existing transportation services. Currently, companies like Boeing, Airbus, Uber, etc. are working to develop air taxi plans.

- Autonomous vehicles: Automated vehicle technologies will minimize the need for drivers, lowering transportation costs, reducing traffic collisions, accidents, and injuries, and lowering CO_2 emissions, while also improving traffic flow and reducing travel time. Self-driving vehicles would expect to interface with sensors in the area, including traffic signs, traffic control systems connected to CCTV networks, and integrated road sensors tracking traffic flow, as well as parking lots.

Moreover, these innovations will develop and provide experiences that reflect future transportation possibilities and will shift the future transportation to fewer traffic congestions, reduced transportation costs, a better environment, safe roads and, reduced travel time.

5. CONCLUSION

The present study analyzed and explored the concept of smart city from a transportation perspective and developments for the future smart transportation in the framework of a smart city, and offer valuable insights and implications into evaluating smart city from a transportation perspective to support city leaders, policymakers, and local governments to reduce traffic congestion and achieve their smart city goal.

The main aim of this study was to develop a better understanding of the smart city, present transport as a component of the smart city, and show smart transportations role in reducing traffic congestion and to fulfill this aim, this study used systematic literature review coupled with bibliometric analysis from most cited publication in the last couple of decades. Finally, a roadmap was introduced based on the obtained data from the systematic review and bibliometric analysis and then provides recommendations that can be used in the future of Istanbul. This roadmap will contribute to the preparation of Istanbul for the future and keeping up with development and a better understanding of the smart city. The proposed roadmap will reduce traffic congestion in Istanbul city and prepare Istanbul for getting closer to its smart city vision as well as laying the foundation for future investigations in the field and provides a valuable reference for academics, practitioners, researchers and scholars in linked research communities, as well as the required contents to inform urban administrators, policymakers and planners about the key obstacles and challenges in developing smart cities. This study limitation was that only final publications published in English language in the engineering area between 2000 and 2021 were chosen from the Scopus database under the smart-city domain. Finally, just because our evaluation focused on smart transportation does not indicate the academic community completely comprehends other components of smart cities.

Future research should investigate developing strategies for relevant emerging future technologies and challenges in the field of smart transportation based on the proposed roadmap, modeling methods and benchmarking with smart cities that already implemented smart transportation, incorporating total transportation management to facilitate governments in their future planning and decision-making process steps for air taxis and air drones.

BIBLIOGRAPHY

Allam, Z., & Newman, P. (2018). Redefining the smart city: Culture, metabolism and governance. *Smart Cities*, *1*(1), 4-25.

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of urban technology*, *22*(1), 3-21.

Anadolu Ajansı, (2019). Turkey should prioritize development of smart cities. Retrieved May 2021 from https://www.aa.com.tr/en/turkey/turkey-should-prioritize-development-of-smart-cities-/1459358

Anthopoulos, L. G. (2017). The rise of the smart city. In *Understanding smart cities: A tool for smart government or an industrial trick?* (pp. 5-45). Springer, Cham.

Apanaviciene, R., Vanagas, A., & Fokaides, P. A. (2020). Smart building integration into a smart city (SBISC): Development of a new evaluation framework. *Energies*, *13*(9), 2190.

Asensio, Á., Blanco, T., Blasco, R., Marco, Á., & Casas, R. (2015). Managing emergency situations in the smart city: The smart signal. *Sensors*, *15*(6), 14370-14396.

Bakıcı, T., Almirall, E., & Wareham, J. (2013). A smart city initiative: the case of Barcelona. *Journal of the knowledge economy*, *4*(2), 135-148.

Bamwesigye, D., & Hlavackova, P. (2019). Analysis of sustainable transport for smart cities. *Sustainability*, *11*(7), 2140.

Barrionuevo, J. M., Berrone, P., & Ricart, J. E. (2012). Smart cities, sustainable progress. *Iese Insight*, *14*(14), 50-57.

Barletta, V. S., Caivano, D., Dimauro, G., Nannavecchia, A., & Scalera, M. (2020). Managing a Smart City Integrated Model through Smart Program Management. *Applied Sciences*, *10*(2), 714.

Bibri, S. E., & Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable cities and society*, *31*, 183-212.

Bıyık, C. (2019). Smart cities in Turkey: Approaches, advances and applications with greater consideration for future urban transport development. *Energies*, *12*(12), 2308.

BMJ. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, *372*, n71.

Caragliu, A., Del Bo, C., & Nijkamp, P. (2013). *Smart cities in Europe* (pp. 185-207). Routledge.

Chen, T. M. (2010). Smart grids, smart cities need better networks [Editor's Note]. *IEEE Network*, *24*(2), 2-3.

Cretu, L. G. (2012). Smart cities design using event-driven paradigm and semantic web. *Informatica Economica*, *16*(4), 57.

Ding, H., Li, X., Cai, Y., Lorenzo, B., & Fang, Y. (2018). Intelligent data transportation in smart cities: A spectrum-aware approach. *IEEE/ACM Transactions on Networking*, *26*(6), 2598-2611.

Dirks, S., & Keeling, M. (2010). A Vision of Smarter Cities: How cities can lead the way into. *Ministry of Science, Technology and Innovation Aras 1-7, Blok C4 & C5, Kompleks C, Pusat Pentadbiran Kerajaan Persekutuan, 62662 Putrajaya, Wilayah Persekutuan.*

European Telecommunications Standards Institute (ETSI). (2016). Intelligent transport systems. Retrieved May 2021 from https://www.etsi.org/technologies/automotive-intelligent-transport

Falconer, G., & Mitchell, S. (2012). Smart city framework. *Cisco Internet Business Solutions Group (IBSG)*, *12*(9), 2-10.

Ghasemi, A., & Saberi, M. (2020). The key factors in transforming Birjand city to a smart city: Smart mobility, smart government. *Indones. J. Electr. Eng. Comput. Sci*, *19*, 317-324.

Giffinger, R., & Gudrun, H. (2010). Smart cities ranking: an effective instrument for the positioning of the cities? *ACE: architecture, city and environment*, *4*(12), 7-26.

Gürcan, Ömer Faruk. (2016). Big Data Applications for Building Smart Cities: A Candidate Smart City-Istanbul

Hamza M.F., Ganesh S.R., Ganesh V.S., Uddin A.A., Ghosh S. (2019). Parking system for smart cities. *International Journal of Recent Technology and Engineering*

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), 1-16.

Ho, G. T. S., Tsang, Y. P., Wu, C. H., Wong, W. H., & Choy, K. L. (2019). A computer vision-based roadside occupation surveillance system for intelligent transport in smart cities. *Sensors*, *19*(8), 1796.

International Telecommunications Union (ITU). (2015). Overview of smart sustainable cities infrastructure. Retrieved May 2021 from http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

International Telecommunications Union (ITU-T), (2015). Focus Group on Smart Sustainable Cities: Overview of smart sustainable cities infrastructure. Retrieved May 2021 from http://www.itu.int/en/ITUT/focusgroups/ssc/Documents/website/web-fg-ssc-0345-r5-ssc_architecture.docx

ISBAK Inc, (2020). Istanbul Computing and Smart City Technologies Inc. Retrieved May 2020 from https://www.isbak.istanbul/

Jeong, S., Kim, S., & Kim, J. (2020). City Data Hub: Implementation of Standard-Based Smart City Data Platform for Interoperability. *Sensors*, *20*(23), 7000.

Khan, S., Nazir, S., García-Magarino, I., & Hussain, A. (2021). Deep learning-based urban big data fusion in smart cities: Towards traffic monitoring and flow-preserving fusion. *Computers & Electrical Engineering*, *89*, 106906.

Komninos, N. (2018). Architectures of intelligence in smart cities: pathways to problem-solving and innovation. *Editorial Board*.

Lee, J. H., Phaal, R., & Lee, C. (2011). An empirical analysis of the determinants of technology roadmap utilization. *R&D Management*, *41*(5), 485-508.

Lee, J. H., Phaal, R., & Lee, S. H. (2013). An integrated service-device-technology roadmap for smart city development. *Technological Forecasting and Social Change*, *80*(2), 286-306.

Lee, J. H., Hancock, M. G., & Hu, M. C. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. *Technological Forecasting and Social Change*, *89*, 80-99.

Lee, W. H., & Chiu, C. Y. (2020). Design and implementation of a smart traffic signal control system for smart city applications. *Sensors*, *20*(2), 508.

Li, G., Cao, N., Zhu, P., Zhang, Y., Zhang, Y., Li, L., ... & Zhang, Y. (2021). Towards Smart Transportation System: A Case Study on the Rebalancing Problem of Bike Sharing System Based on Reinforcement Learning. *Journal of Organizational and End User Computing (JOEUC)*, *33*(3), 35-49.

Linares Herreros, M. P., Montero Mercadé, L., & Casanovas Garcia, J. (2019). A traffic simulation tool for assessing smart city policies (CitScale). *Computing in science and engineering*.

Lombardi, P., Giordano, S., Farouh, H., & Yousef, W. (2012). Modelling the smart city performance. *Innovation: The European Journal of Social Science Research*, *25*(2), 137-149.

Luo, Y., Zhu, X., & Long, J. (2019). Data collection through mobile vehicles in edge network of smart city. *IEEE Access*, *7*, 168467-168483.

Lücken, V., Voss, N., Schreier, J., Baag, T., Gehring, M., Raschen, M., ... & Ascheid, G. (2018). Density-based statistical clustering: enabling sidefire ultrasonic traffic sensing in smart cities. *Journal of Advanced Transportation*, *2018*.

Magsino, E. R. (2020). Centralized smart parking and insurance applications for intelligent vehicles in a smart city utilizing the cloud computing paradigm. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*(4), 5471.

Mkrtychev, O., Starchyk, Y., Yusupova, S., & Zaytceva, O. (2018, June). Analysis of various definitions for Smart City concept. In *IOP Conference Series:*

Materials Science and Engineering (Vol. 365, No. 2, p. 022065). IOP Publishing.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS medicine*, *6*(7), e1000097.

Mori, K., & Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI). *Environmental impact assessment review*, *32*(1),

Money Talks-Trtworld (2019, April 12). *Istanbul gets smart to solve traffic congestion | Money Talks***.** Retrieved May 2020 from https://www.trtworld.com/video/money-talks/istanbul-gets-smart-to-solve-traffic-congestion-money-talks/5cb0664188a00461c7d32c44

Nam, T., & Pardo, T. A. (2011, June). Conceptualizing smart city with dimensions of technology, people, and institutions. In *Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times* (pp. 282-291).

Nguyen, D. D., Rohács, J., Rohács, D., & Boros, A. (2020). Intelligent Total Transportation Management System for Future Smart Cities. *Applied Sciences*, *10*(24), 8933.

Niculescu, A. I., Wadhwa, B., & Quek, E. (2016). Smart city technologies: design and evaluation of an intelligent driving assistant for smart parking. *International Journal of Scientific Engineering and Technology (IJASEIT)*, *6*(6), 1096-1102.

Niu, X., Zhu, Y., Cao, Q., Zhang, X., Xie, W., & Zheng, K. (2015). An online-traffic-prediction based route finding mechanism for smart city. *International Journal of Distributed Sensor Networks, 11*(8), 970256

Nowicka, K. (2014). Smart city logistics on cloud computing model. *Procedia-Social and Behavioral Sciences*, *151*, 266-281.

Ochoa Guevara, N. E., Diaz, C. O., Dávila Sguerra, M., Herrera Martinez, M., Acosta Agudelo, O., Ríos Suarez, J. A., ... & López Garcia, A. C. (2019). Towards the design and implementation of a Smart City in Bogotá, Colombia. *Revista Facultad de Ingeniería Universidad de Antioquia*, (93), 41-56.

Pawłowska, B. (2018). Intelligent transport as a key component of implementation the sustainable development concept in smart cities. *Transport Economics and Logistics*, *79*, 7-21.

Paiva, S., Ahad, M. A., Tripathi, G., Feroz, N., & Casalino, G. (2021). Enabling Technologies for Urban Smart Mobility: Recent Trends, Opportunities and Challenges. *Sensors*, *21*(6), 2143.

Probert, D. R., Phaal, R., & Farrukh, C. J. P. (2003). Technology roadmapping: Linking resources to strategic goals. *Paper based on the research project, Strategic technology management: linking technology resources to business objectives, EPSRC project GR L, 62900*.

Petrick, I. J., & Echols, A. E. (2004). Technology roadmapping in review: A tool for making sustainable new product development decisions. *Technological Forecasting and Social Change*, *71*(1-2), 81-100.

Ramos, F., Trilles, S., Muñoz, A., & Huerta, J. (2018). Promoting pollution-free routes in smart cities using air quality sensor networks. *Sensors*, *18*(8), 2507.

Saggese, S., Sarto, F., & Cuccurullo, C. (2016). Evolution of the debate on control enhancing mechanisms: A systematic review and bibliometric analysis. *International Journal of Management Reviews*, *18*(4), 417-439.

Smart Cities Index. (2020). IMD Business School. Retrieved May 2021 from https://www.imd.org/smart-city-observatory/smart-city-index/

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222.

TomTom Traffic Index (2020). Available at: https://www.tomtom.com/traffic-index/ranking/.

UN (2011). World urbanization prospects: The 2011 revision. UN Department of Economic and Social Affairs, Population Division.

UN (2020). UN-Habitat Global Database of Metropolises 2020 available in https://qrco.de/UNHabitat_GlobalDatabaseOfMetropolis2020

Winden, v., W., & van den Buuse, D. (2017). Smart city pilot projects: Exploring the dimensions and conditions of scaling up. *Journal of Urban Technology*, *24*(4), 51-72.

Wang, C., David, B., Chalon, R., & Yin, C. (2016). Dynamic road lane management study: A Smart City application. *Transportation research part E: logistics and transportation review*, *89*, 272-287.

Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N., & Nelson, L. E. (2009). Helping CIOs understand “smart city” initiatives. *Growth*, *17*(2), 1-17.

World Population (2021). Retrieved May 2021 from https://worldpopulationreview.com/world-cities/istanbul-population

Yang, Y. S., Lee, S. H., Chen, G. S., Yang, C. S., Huang, Y. M., & Hou, T. W. (2020). An implementation of high efficient smart street light management system for smart city. *IEEE Access*, *8*, 38568-38585.

Yun, Q., & Leng, C. (2020). Intelligent Control of Urban Lighting System Based on Video Image Processing Technology. *IEEE Access*, *8*, 155506-155518.

Zaheer, T., Malik, A. W., Rahman, A. U., Zahir, A., & Fraz, M. M. (2019). A vehicular network–based intelligent transport system for smart cities. *International Journal of Distributed Sensor Networks*, *15*(11), 1550147719888845.

Zhang, Y., Zhang, G., Fierro, R., & Yang, Y. (2018). Force-driven traffic simulation for a future connected autonomous vehicle-enabled smart transportation system. *IEEE Transactions on Intelligent Transportation Systems*, *19*(7), 2221-2233.

Zhou, L., Li, Q., & Tu, W. (2020). An Efficient Access Model of Massive Spatiotemporal Vehicle Trajectory Data in Smart City. *IEEE Access*, *8*, 52452-52465.

Zygiaris, S. (2013). Smart city reference model: Assisting planners to conceptualize the building of smart city innovation ecosystems. *Journal of the knowledge economy*, *4*(2), 217-231.

APPENDICES

APPENDIX A-INFORMATION ABOUT THE POPULATION LEVEL AND GROWTH RATE FOR ISTANBUL FROM 1950-2021.

Year	Population	Growth-Rate	Growth
1950	967497	0	0
1951	1018151	0.0524	50654
1952	1071531	0.0524	53380
1953	1127552	0.0523	56021
1954	1186585	0.0524	59033
1955	1248709	0.0524	62124
1956	1294349	0.0365	45640
1957	1332337	0.0293	37988
1958	1371494	0.0294	39157
1959	1411802	0.0294	40308
1960	1453353	0.0294	41551
1961	1534902	0.0561	81549
1962	1640147	0.0686	105245
1963	1752608	0.0686	112461
1964	1872951	0.0687	120343
1965	2001192	0.0685	128241
1966	2136617	0.0677	135425
1967	2280326	0.0673	143709
1968	2433920	0.0674	153594
1969	2597394	0.0672	163474
1970	2772095	0.0673	174701
1971	2931066	0.0573	158971
1972	3085926	0.0528	154860
1973	3248509	0.0527	162583
1974	3419899	0.0528	171390
1975	3600332	0.0528	180433
1976	3759125	0.0441	158793
1977	3909144	0.0399	150019
1978	4065369	0.04	156225
1979	4227838	0.04	162469
1980	4397037	0.04	169199
1981	4580127	0.0416	183090
1982	4774228	0.0424	194101
1983	4976556	0.0424	202328
1984	5187754	0.0424	211198
1985	5407297	0.0423	219543
1986	5623536	0.04	216239
1987	5842560	0.0389	219024
1988	6070435	0.039	227875
1989	6306534	0.0389	236099

APPENDIX A: Continued

1990	6552160	0.0389	245626
1991	6773134	0.0337	220974
1992	6986256	0.0315	213122
1993	7205470	0.0314	219214
1994	7431880	0.0314	226410
1995	7665403	0.0314	233523
1996	7906601	0.0315	241198
1997	8154694	0.0314	248093
1998	8367183	0.0261	212489
1999	8553323	0.0222	186140
2000	8743868	0.0223	190545
2001	9030318	0.0328	286450
2002	9369562	0.0376	339244
2003	9721551	0.0376	351989
2004	10087275	0.0376	365724
2005	10465694	0.0375	378419
2006	10858861	0.0376	393167
2007	11266798	0.0376	407937
2008	11690655	0.0376	423857
2009	12129224	0.0375	438569
2010	12584885	0.0376	455661
2011	13057664	0.0376	472779
2012	13419412	0.0277	361748
2013	13658365	0.0178	238953
2014	13901910	0.0178	243545
2015	14126772	0.0162	224862
2016	14332066	0.0145	205294
2017	14539767	0.0145	207701
2018	14750771	0.0145	211004
2019	14967667	0.0147	216896
2020	15190336	0.0149	222669
2021	15415197	0.0148	224861
2022	15636243	0.0143	221046
2023	15847768	0.0135	211525
2024	16047350	0.0126	199582
2025	16236703	0.0118	189353
2026	16419127	0.0112	182424
2027	16597380	0.0109	178253
2028	16773738	0.0106	176358
2029	16949438	0.0105	175700
2030	17124240	0.0103	174802
2031	17298572	0.0102	174332
2032	17473084	0.0101	174512
2033	17647434	0.01	174350
2034	17819272	0.0097	171838
2035	17986296	0.0094	167024