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THE QUALITY OF SMART MOBILITY: A SYSTEMATIC REVIEW

Summary. Smart cities and smart mobility are often analysed by systematic, sustainability-related, informatical, etc., issues. However, the quality elements of smart mobility services have not yet been reviewed. In this paper, we reviewed smart cities and smart mobility as well as the quality elements of smart mobility services. Based on the reviewed literature, we illustrated the requirements against smart mobility and uncovered the need for optimisation. We also interpret a monitoring method based on SERVQUAL. This method can be a base of establishing key performance indicators as well as benchmarking between cities.
Keywords: smart mobility, quality, optimisation, SERVQUAL

1. INTRODUCTION

Interest towards service quality has been increased greatly during the 1980s. The growing markets and escalating race for customers forced organisations to review their processes. In recent decades, sustainability became increasingly important [4,11,24]. The concept of smart cities is related to sustainability, as well as information and communications technology (ICT), demand-driven services and quality of life. Smart cities are complex systems. One of its sub-

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systems is smart mobility, which focuses on either freight or passenger transportation-related issues. Service planning in smart mobility has various new challenges related to this new environment.

This research is aimed at uncovering the service quality elements of smart mobility. Several quality concepts, theories and service quality tools are present, the adaptation for smart mobility, however, not yet been done. Interpretation and complex adaptation of various quality management techniques can greatly increase the efficiency of service planning and development.

2. LITERATURE REVIEW

We review the state of the art in two major fields: smart cities and service quality. Smart city-related literature includes sustainability, ICT applications, certain social or economic issues. Service quality has a rich research background. While adapting to certain models and methods, we focused on three main elements: formalised quality systems (EN 13816), service quality models (Gap-model, SERVQUAL) and practical quality theories (TQM, Lean, Six Sigma).

2.1. Smart cities and smart mobility

In the past years, two major tendencies may be observed: (1) the demand for a sustainable practice and (2) an emerging re-urbanisation process. In this section, we review sustainability, smart cities and smart mobility. Sustainability has been researched in many aspects: environmental [13,15,16,21,37], social [1,20,30], economic [7,12], etc., issues. The concept of smart cities practically focuses on urban transformation, based on sustainability. However, as every society can be described by economic, social, environmental and institutional dimensions, smart cities and sustainability shall adopt these elements as well. Next to the given tendencies, ICT applications and information or knowledge-based societies emerge. Technologies for transport face great challenges by globalisation, re-urbanisation and the change of social mobility behaviour. Passenger transportation is an indispensable and elementary service. They require personalised services and tend to use their own private cars [9]. Next to passenger transportation, delivery services are also present in urban areas. By the increasing number of web-based shops, the volume of freight traffic increases correspondingly. For the current problems serves several answers, one of the smart cities' sub-systems, smart mobility [33,36]. Smart mobility consists of several elements and goals, the most common ones can be observed in Fig. 1.

We separated smart mobility into two segments: (1) innovative solutions and (2) development of current services. In the figure, the most relevant issues were illustrated in both segments, with light-blue oval boxes. White oval boxes present some examples based on literature.

Innovative solutions are not present in every urban transportation system, however, it plays a main role in smart mobility-oriented development. Autonomous vehicles (AV) and electric vehicles (EV) are tools on the vehicle side. Mobility as a Service (MaaS) is a new concept [17], with which demand-driven service planning and personalisation of services are possible. Shared mobility solutions are effective tools to increase the efficiency of cars. While developing the current services, the usage of innovative solutions is recommended. In the field of city logistics EVs, electric cargo bikes (E-CB), new modelling and traffic control techniques are available

[2,31,32]. ICT applications (hardware and software) demand-driven solutions are spreading. Parking services are also moving to automated solutions; P+R parking lots and connectivity with public transportation network are the most important issues. One of the latest research directions is urban space-saving by normalising parking issues.

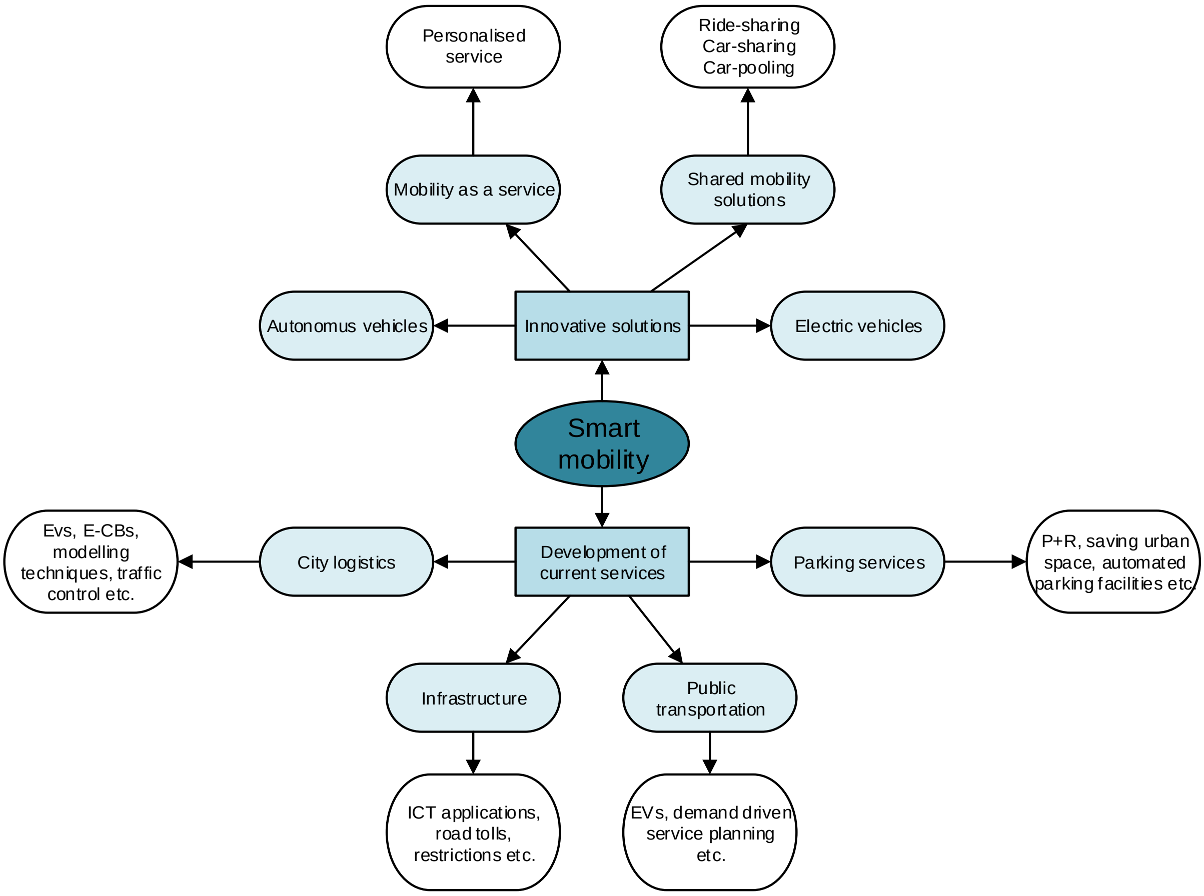

Fig. 1. The main elements of smart mobility

2.2. Service and transportation quality

Quality has several definitions, which varies between production and service sectors. The concept of quality has changed over the years. As markets globalised, production organisations and service providers must face an escalating race for customers. We reviewed three main areas (Fig. 2): formalised quality systems, theoretical quality concepts and service quality tools.

Formalised quality management systems are often considered as instruments of quality and service process definitions. We reviewed two authoritative systems: EN 13816 and the Transit Capacity and Quality Service Manual (TCQSM, 3rd edition, 2013). They classify service characteristics; TCQSM contains five main aspects: quality of service, capacity, speed and reliability, definitions and local data [23]. EN 13816, as a European Standard specifies the requirement to define, target and the measure quality of service in various areas of transportation (for example, public transportation, logistics) as well as guidance to implement those specified. Formalised systems are capable of removing functional barriers as well as increase cross-functional processes in an organisation.

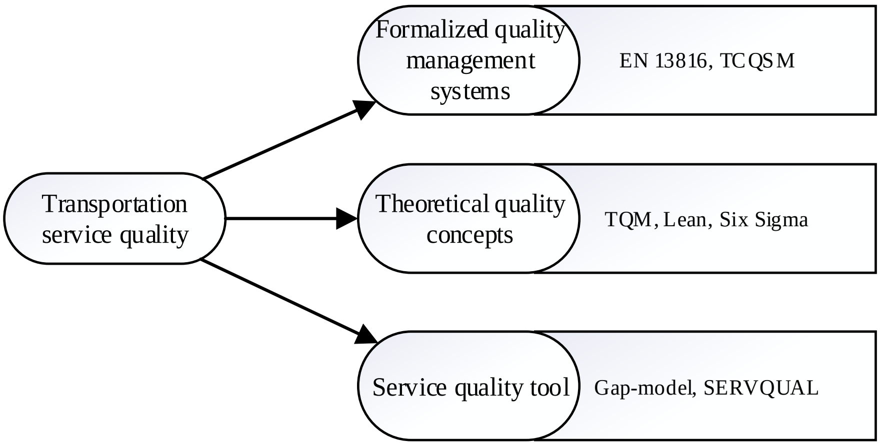

Fig. 2. The reviewed quality management concepts

Three theoretical (or as often called: philosophical) quality concepts have been reviewed. They are TQM, Lean and Six Sigma [22]. We summarised the goals and base methods of each concept, as well as the adaptation for transportation services and organisations in Tab. 1.

Tab. 1

The reviewed theoretical quality concepts

Concept	Goal (G) and base method (BM)	Adaptation
Six Sigma	G: to reduce cost, by reducing variability BM: mathematical-statistical tools	Standardise organisational processes, decrease the variability of services (for example, consistent waiting times, low delay)
Lean	G: to make organisations more competitive; increase efficiency, eliminate non-value adding steps, reduce cycle times BM: value stream mapping	Review and increase the efficiency of organisational processes; understand organisational processes and sub-systems (for example, HR, PR, service planning, etc.)
TQM	G: to achieve a continuous development process BM: soft methods, self-improvement, bench-marking	Building a continuous development process in the organisation, ensuring the monitoring and development of services

Based on the literature [8], the best interpretation is "*Six Sigma quality, Lean production and TQM company culture"*. Lean and Six Sigma combined has been applied for many years. Lean-Six Sigma (L6σ) is considered a highly effective instrument for quality and efficiency maximisation. It combines Six Sigma's focus on eliminating variability and Lean's focus on waste and cycle time elimination [29]. The interpretation of Lean elements for services is difficult. Waste and cycle time elimination means increasing efficiency and competitiveness in organisations as well as in services.

Service quality is not easily articulated by customers. It has been defined and measured with several methods, one of which is Parasuraman et al. (1985) SERVQUAL model [2]. This model has been refined several times [25,26] by the authors. Services can be described by three well-documented characteristics: *intangibility, heterogeneity and inseparability*. Services are intangible when compared to the physical goods in the production sector. Services have a social impact, elements. To understand service quality, we started from the 'Gap model', which was defined by Parasuraman et al. (1985). In Fig. 3, we adapted it to mobility.

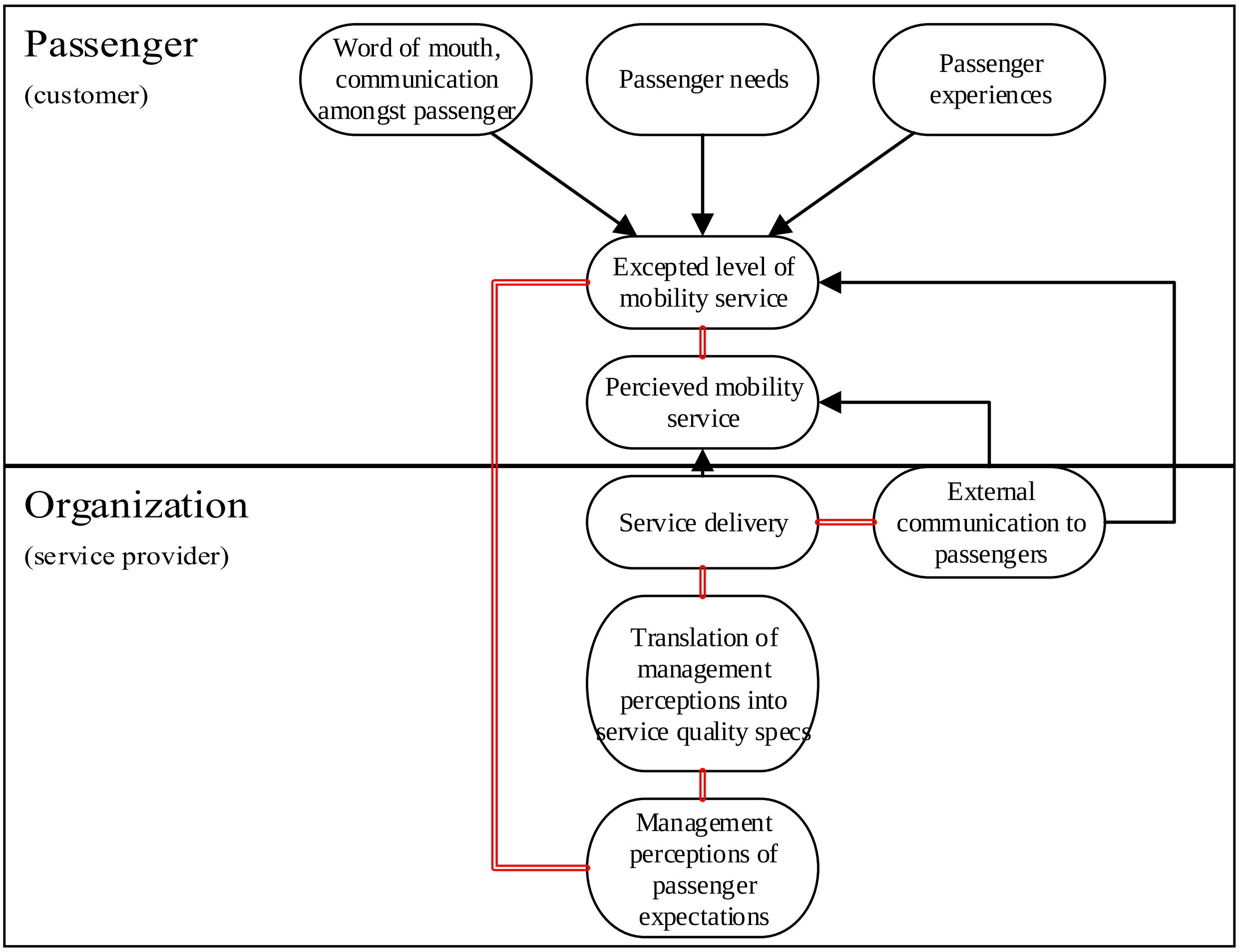

Fig. 3. The gap-model adapted to mobility services

In Fig. 3, gaps are illustrated with red lines, while the flow of information with arrows. Two main ideas are in focus: first, the service provider must translate passenger needs, understand and implement them in mobility solutions. Second, adapting quality management systems aims to monitor passenger needs and experiences, while understanding the weak points of certain services. The development and the application of quality management systems and methods aimed at demand-driven service planning and continuous development. Lastly, SERVQUAL offers organisations, developers and service planners, a multi-dimensional scale to measure service quality. Consistent monitoring of passenger needs, expectations and experiences can be applied as a base of continuous development. Monitoring, in this context, means that the service provider constantly monitors passenger needs with, for example, phone application. The data collected is handled and analysed dynamically. The development of services is based on this.

Using quality management techniques in smart mobility development has several practical advantages. In the following section, we introduce the system of requirements and demands as well as a handling method.

3. PRACTICAL ISSUES OF SERVICE PLANNING AND DEVELOPMENT

In a smart city, the quality of transportation services can be approached in a complex way. Based on the concept of smart cities and smart mobility, demand-driven service planning and personalised services are recommended; accordingly, it is important to understand and define demands.

3.1. Requirements against services and optimisation

When planning mobility services, we try to understand passenger needs. For this, we can use the various quality instruments as shown in the literature. However, certain environmental and social requirements are present as well. International organisations (for example, UN, EU), for decades, have environmental and social declarations, guidelines, standards or regulations. National governance tends to be more focused on sustainability as well. In addition, international corporations prepare more sustainability reports and strategies of corporate social responsibility have spread in recent years as well [10,28].

While developing and configuring mobility services, the service planner ought to optimise between passenger, environmental and social requirements. In Tab. 2, we summarised the most relevant requirements, as well as some further references.

Tab. 2

The most relevant requirements towards smart mobility services

Group	Requirements	Further references
Passenger	Safety, flexibility, speed, low delay, consistent schedule, comfortable vehicles and stations, support of smart devices, suitable application, electronic ticketing system, etc.	Public transportation [18], ITS application in integrated ticketing system [5].
Environmental	Decreasing emission, noise pollution, energy consumption, applying new energy resources, new power technologies, optimising land use, etc.	Environmental impact of biofuels and fuel cells [6], sustainability indicators of urban transport [14].
Social	Accessibility for handicapped passengers, sustainable and equitable tariff system,	Social costs of urban transportation, optimal pricing [3].

On the one hand, the given requirements are, in most contexts, conflicting with each other. For example, a private car is flexible, comfortable, but in an urban environment, most externalities come from private car usage. On the other hand, these requirements are correlating with each other as well. Biofuels and fuel cells, electromobility, as well as autonomous and shared cars are opening new perspectives in transportation, which require a new quality management and planning approach.

To reduce environmental and social externalities, preference of public transportation and track-based modes (for example, tram, metro trains) are suggested. Social sustainability may be increased by applying an integrated information technology-based equitable ticketing system. Such ticketing system should be based on smart devices and applications. The pricing may vary by peak or off-peak hours, mode, location, travel distance, etc. This application, next to optimal pricing, serves a good base for monitoring passenger requirements and experiences.

While developing or planning services influencing passenger behaviour, a complex approach is recommended. Including the reviewed requirements, it is important to achieve a more sustainable practice.

3.2. Monitoring and benchmarking performance

To implement a smart development, application of quality and transportation management techniques are needed. Passenger requirements and expectations may be monitored through an application. Based on SERVQUAL, the approach of quality, by passenger expectations may be done, as seen on (1).

$$SQ = E - D \tag{1}$$

where, SQ is service quality, E is passenger experience and D is demand. Both experience and demand are measured with a discrete Likert-scale. When analysing urban passenger transportation systems in a case study of Budapest, we found that it is practical to separate the whole system to *performance objectives (PO).* In Tab. 3, we concluded nine POs with short descriptions.

Tab. 3

Performance objectives of urban passenger transport systems

Performance objective	Description
Environmental sustainability	Vehicle parameters (EVs, biofuel, etc.), public space (parking management), green areas (parks, rest areas), etc.
Safety	Vehicle and infrastructure, emergency handling, passenger feelings, etc.
Accessibility (physical and social)	Vehicles and stations, infrastructure, tariff system, etc.
Reliability and consistency	Consistent public transport schedules and delays, etc.
Integration of micro-mobility	Bike lanes, bike-sharing services, integration level, etc.
Integration of information and communications and technology (ICT)	ICT hardware and software integration (for example, devices in stations, route planning application, etc.), Wi-Fi access, etc.

For all POs, we estimated *passenger performance,* based on the SERVQUAL model. This performance states the current performance of the service on a given objective (2).

$$Perf_{pass}^{i} = \sum_{j=1}^{n} E_j - I_j \tag{2}$$

Equation 2 illustrates the passenger performance of PO i ($Perf_{pass}^{i}$). We asked n passengers, how important a certain issue is and how well does the current system perform. I stands for the importance of PO i. Inside one PO, there were multiple questions, these questions are interconnected.

In our previous research, we ranked POs by importance and developed *key performance indicators* (KPI) for Budapest. KPIs are more focused on certain issues, for example, the accessibility of stations (inside PO accessibility). The KPIs were driven by passenger demands based on the uncovered importance. To achieve a smart practice, we may increase the importance of environmental and social issues. For example, KPIs connected to the objective of environmental sustainability has the importance level increased. Optimisation can be implemented based on passenger demands. A simple way is to modify the importance values, given by passengers, as in (3).

$$Perf_{mod}^{i} = \sum_{j=1}^{n} (E_j - I_j + \alpha) \quad (3)$$

where α is a modification parameter, its value should be defined by city development strategies. The main question regarding value is *how much does the service planner want to increase certain POs?* The values of modification parameters may vary according to the fields of sustainability (environmental, social, economic) as well. For example, if the strategy prefers social sustainability over environmental, the value of the parameter should be greater for social issues.

Benchmarking between cities may ease the process of service development. Smart cities are interconnected by ICT. To decrease time and effort spent on solving various problems, we suggest implementing a consistent measurement system and applying it to all cities on a national basis. Benchmarking makes it easier to build up a continuous monitoring and development system too. In Fig. 4, we illustrated a development and planning method for three cities.

Services are planned and developed on two levels: strategic and operative. First, strategic planning happens on a high level. Cities should develop their strategies aiming towards smart city goals. Goals should be well defined and interpreted as missions (based on TQM). This strategy is based on passenger, environmental and social demands. Operative development is adjusted to the strategy and focuses on a certain service (for example, public transportation). Through the whole development process, passenger demands, and the effect of operative improvements on services are monitored and handled dynamically.

4. DISCUSSION

In this research, we reviewed the state of the art regarding smart cities, service quality and transportation externalities. Applying various techniques is mandatory; sustainability as a goal does not always mean the best practice for every stakeholder group.

We found that management techniques can mainly be interpreted on two levels: strategic and operative. Based on the presented planning-development process, a new management technique can be defined. Strategic planning should be done by governments while operative planning by the service providers. Through the planning and development of services, benchmarking is recommended. This way cities would progressively move towards smarter practices.

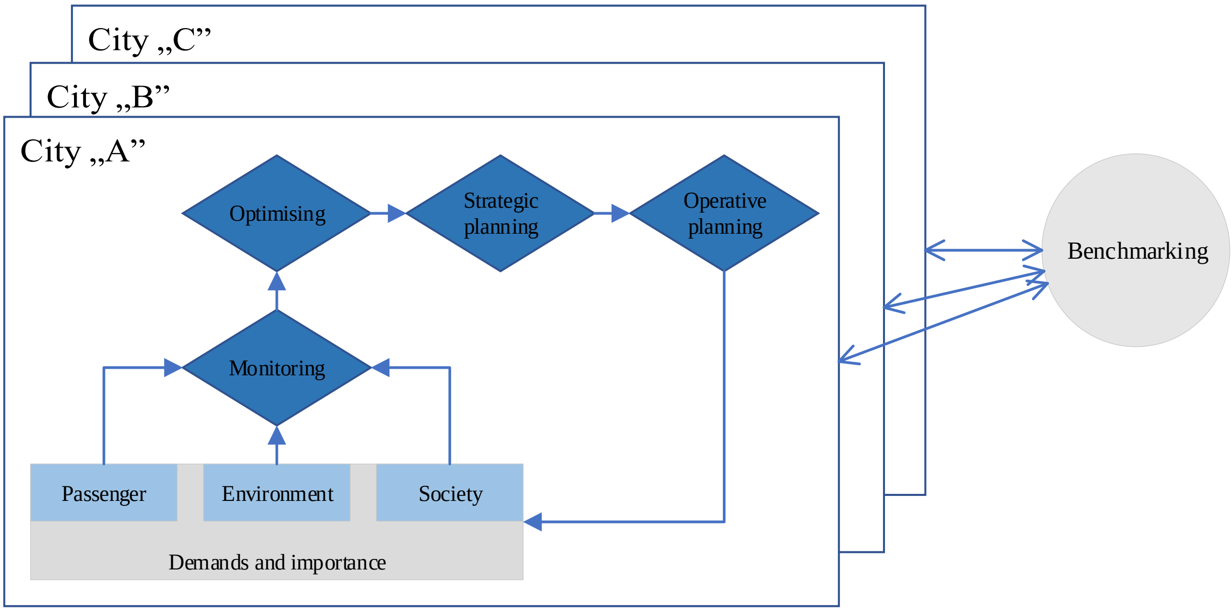

Fig. 4. Smart planning-development process and benchmarking

We discovered that various demands are present concerning transportation services. The complex handling of passenger demands, environmental and social variables is recommended. This handling method may be based on quality management theories done by quality management instruments. It is recommended to establish a continuous development process, monitoring system and database inside and between cities.

The quality of smart mobility should be interpreted at a strategic level. According to TQM, strategic goals should be missions, with which all stakeholders (governments, service providers, and citizens) should identify with.

5. CONCLUSION

Based on smart city approaches and service quality concepts, we reviewed the quality of smart mobility. Based on the reviewed literature, we concluded that *service quality in smart cities are complex and requires a new set of measurement and planning skills and methods.*

Sub-systems (for example, smart mobility and urban development) and requirements (passenger, environment, society) are interconnected, requiring complex handling. The optimisation of requirements and demands is difficult and should be done by governments on a strategic level. Optimisation requires a clear and well-defined strategy.

Various quality management techniques are present. To achieve smart practice in urban development, governments and service providers should apply them. We found that based on SERVQUAL, the creation of a KPI system can be done. In this KPI system, based on the strategy, optimisation may happen.

Further directions based on this research may be the exact developing of the optimisation technique. Our future work aims at the analysis of service quality issues in smart mobility with econometric and operation's research techniques. We would like to achieve a framework to increase service quality.

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