Chapter

Reshaped Urban Mobility

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Abstract

The application of novel solutions in vehicle and information technologies and the need for sustainability result in significant change in urban mobility. Moreover, autonomous vehicles (AVs) are expected to contribute to this alteration as well. The mobility is considered not only a single trip from A to B anymore but a comprehensive service. Shared and demand-driven services are more and more available besides traditional transportation modes. Modes are presented, evaluated, and compared, giving a realistic scenario for upcoming changes and opportunities. The development of the passenger transportation system requires an integrated approach considering user expectations. It is facilitated by the concept of Mobility-as-a-Service (MaaS), in which improvement of the quality has higher relevance than before. The impacts of the alteration are also summarized.

Keywords: autonomous vehicles, demand-driven, future mobility, impacts, Mobility-as-a-Service, passenger transportation system, shared urban mobility

1. Introduction

Passenger transportation, accessibility, land use, and activities interact with each other. On the one hand, passenger transportation provides the adequate circumstances of every movement. On the other hand, its effect on the environment is negative (e.g., traffic accidents, energy consumptions, pollution, land use).

Mobility is the complexity of transportation processes derived from the spatial characteristics of human needs and activities. It includes the flow of persons, goods, and information, as well as information processes related to them. In cities, the demands are concentrated resulting in a high volume of traffic.

Sustainable mobility means a long-term and balanced relationship among environment, economy, society, and transportation system. Accordingly, substantial alteration is required by introducing such innovative solutions that provide the adaptivity of the system. During the development, the aim is to apply such solutions that manage the resources efficiently while satisfying travelers' preferences [1].

In this chapter, we summarize the knowledge related to the reshaping of urban passenger mobility based on literature review and our previous studies. The topic is discussed by a transportation engineering point of view. We focus both on management- and traveler-related issues, highlighting social effects instead of technical details.

The chapter proceeds as follows: Section 2 provides a thorough overview and comparison of current traditional and novel urban transportation modes and mobility services. In Section 3, the alteration in mobility services is discussed with a special focus on automation and autonomous vehicles (AVs). Section 4 describes the planning principles of novel mobility services highlighting user expectations. In Section 5, Mobility-as-a-Service (MaaS) concept is detailed with special regard to quality. Section 6 presents the major impacts of novel mobility services on the urban environment. In the last section, the research is concluded, emphasizing the key findings, and the future research directions are given.

2. Mobility services

Transportation modes are defined as the means of transportation and their attributes. Individual and collective modes are distinguished. Besides them, so-called transitional modes are spreading. The attributes of transitional modes are to be defined between that of individual car use and traditional public transportation. Typically, either the time frame of a vehicle or the available seats of a vehicle are shared. The sharing facilitates the efficient allocation of the available sources. Either demand-responsive or demand-driven (on-demand) mobility services are provided. In demand-responsive services, flexible schedules are applied, and the capacity reflects the demands [2]. Demand-driven services are operated only if any demand arises. The routes and schedules are not predetermined [3]. At these modes, the ordering (demand announcement) in advance is usually mandatory. The real-time demand-capacity coordination and management of the services are based on an advanced infocommunication system. Several transitional modes are available only via a smartphone application. Mobility services can be defined as joint activities that provide the transportation capacities, technological processes, and related (information) services (e.g., seat reservation). Description of typical urban transportation modes and services is summarized in **Table 1**.

Walking is incorporated into every trip. Access to the departure point and egress from the destination point, as well as transfer between the modes, require walking. It is competitive for a short range. The so-called soft mobility forms cover micromobility, namely small-sized (one or two seats) human or electric-driven vehicles (e.g., bicycle, pedelec, Segway, scooter). They are used for the last miles. These vehicles are operated in shared mobility services as well.

Transportation modes and mobility services can be categorized according to several attributes. The knowledge of these attributes is necessary to sufficiently serve the travel demand and remain competitive. The most important categorization aspects of transportation modes are as follows (**Figure 1**):

- Modality of vehicle use (individual or collective)
- Vehicle proprietor (service company or private person)
- Driver (traveler or professional driver)

The selection of a mobility form for a specific trip is influenced by several aspects at the same time. Transportation modes can be compared, among others, according to travel distance, the regularity of traveling, the number of passengers, and flexibility. Detailed flexibility analyses focus on the following attributes:

- Spatiality—e.g., departure and destination point, coverage, availability, travel distance, and the fixity of the routes
- Temporality—e.g., accessibility (operation time), timetable, waiting time, service time, time units of the use, and the minimum time of use
- User target group

Transportation modes	Description
Public transportation	Supply-based services which are accessible for anyone at a specified location (stop), at a specified time (according to timetable), on a specified route (line), according to the specified terms and conditions, for a specified fee
Demand-responsive transportation	Flexible mobility service in space and/or in time which can be used only after request, often with the same tariff as the traditional public transportation has. It is operated typically in a sparsely populated area or in time periods when travel demand is low
Vehicle-sharing (bike-sharing/car-sharing)	Shared use (in time) of a publicly or privately owned vehicle. The vehicles are available for anyone for a (time-based) fee. It is typically used for a short-range, urban ride, for a short term
Ride-sharing	Capacity (seat) sharing of a privately owned vehicle to share the travel cost. Typically, a slightly regulated, nonprofit transitional mode for a long-range travel. The driver offers the free seats of the vehicle
Taxi	Strongly regulated profit-oriented transportation mode typically for a short-range, urban ride. It provides a door-to-door, high-quality ride for a high fee
Ride-sourcing	Application-based ride management. Travel demand and capacity are coordinated automatically. The mode is preferred for a short-range, urban ride, like the taxi service. It provides door-to-door service with slight regulation, applying dynamic tariff system
Chauffeur service	Traveling in our own car as a passenger with a "hired" driver. Typically, it is used for the sake of convenience, usually at night, when the traveler is not capable of driving or wishes to do other activities during the travel
Individual car/motorcycle/ bicycle	Using a privately owned vehicle for an individual trip; neither the vehicle nor the seat is shared with unknown travel mates

Table 1.
Description of transportation modes (source: based on [4]).

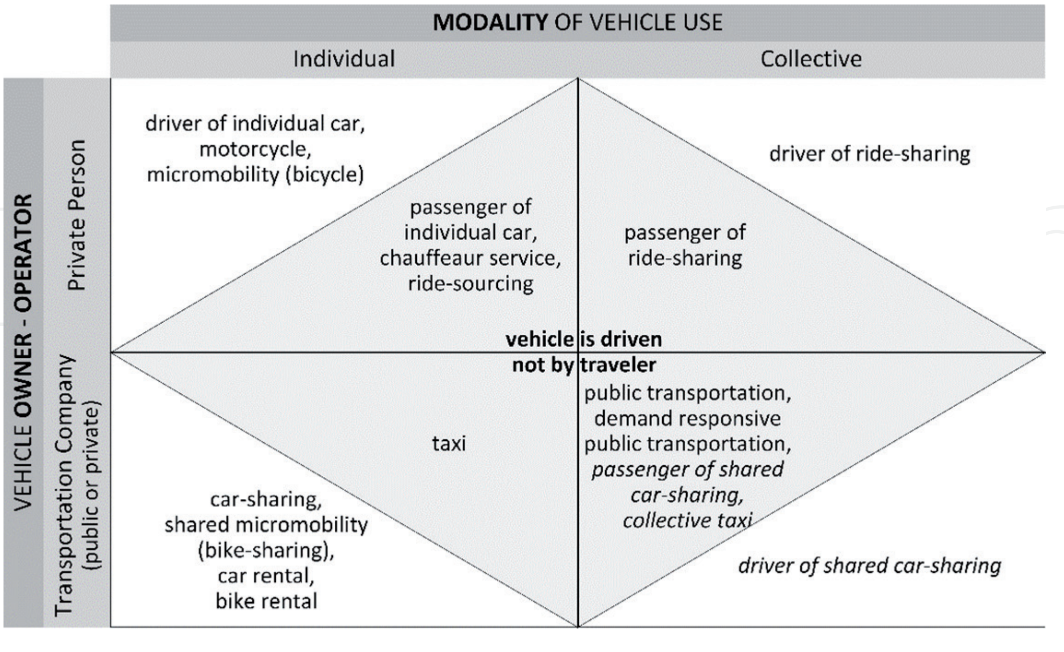

Figure 1.
Classification of current passenger transportation modes (source: based on [4]).

- Attributes of ordering
- The degree of spread

- Type of the applied infocommunication system and services
- Attributes of the fee collection system—e.g., method of fee calculation and payment
- Need for additional tasks—e.g., maintenance and repair
- Type of operation—e.g., publicly or privately owned vehicles [4]

The attributes influence modal share and travel chains. Modal share is a set of indicators which show the percentages of travelers using particular transportation modes in terms of either the number or the length of the trips. Usually walking, cycling, car use, and public transportation are considered. Although the use of transitional modes is constantly increasing, their modal share is still exiguous.

Travel chain is defined as the combined use of different modes and services during a trip. The aims of forming travel chains are:

- To extend the supply of passenger transportation
- To combine the partial advantages of transportation modes

During the formation of an integrated travel chain, the combination of transportation modes is to be planned to provide similar mobility opportunity and service level than that of individual transportation. If a travel chain including a public transportation service provides favorable mobility opportunity according to flexibility and service quality, the share of public transportation can be enhanced. The "weakest link" determines the "strength" of a travel chain. The transfer is the critical part of a chain. The transfers between means and modes are performed at stops and in stations as well as at intermodal junctions. The quality of the mobility service is influenced by, besides the quality attributes of each mode, the design of the intermodal junctions (e.g., walking distances) and the quality of the available supplementary services (e.g., information provision). The common targets during the combination of transportation modes are to minimize the time spent in the system and the fee to be paid while maximizing the perceived service quality.

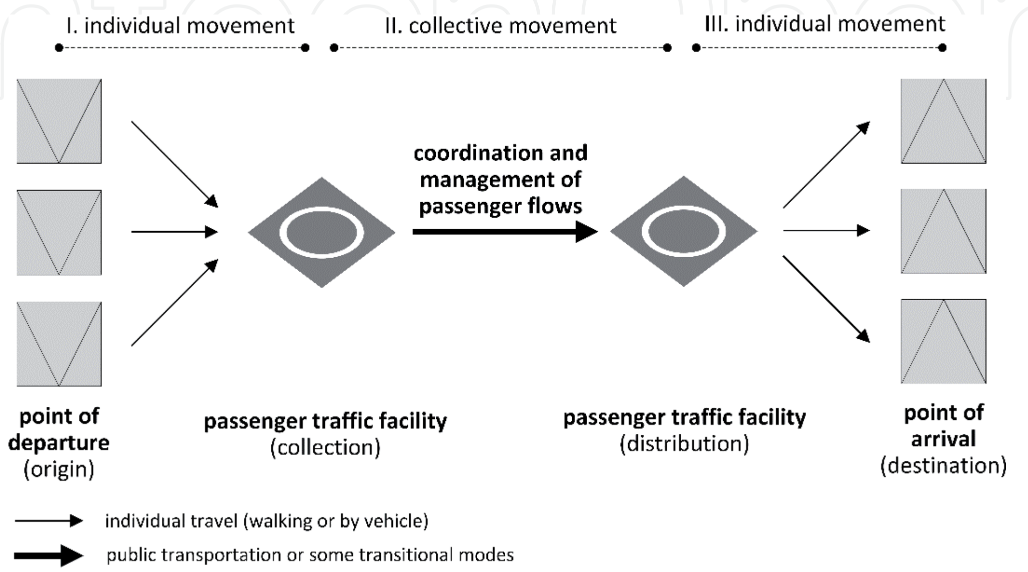

Figure 2.
Model of travel chain (source: [4]).

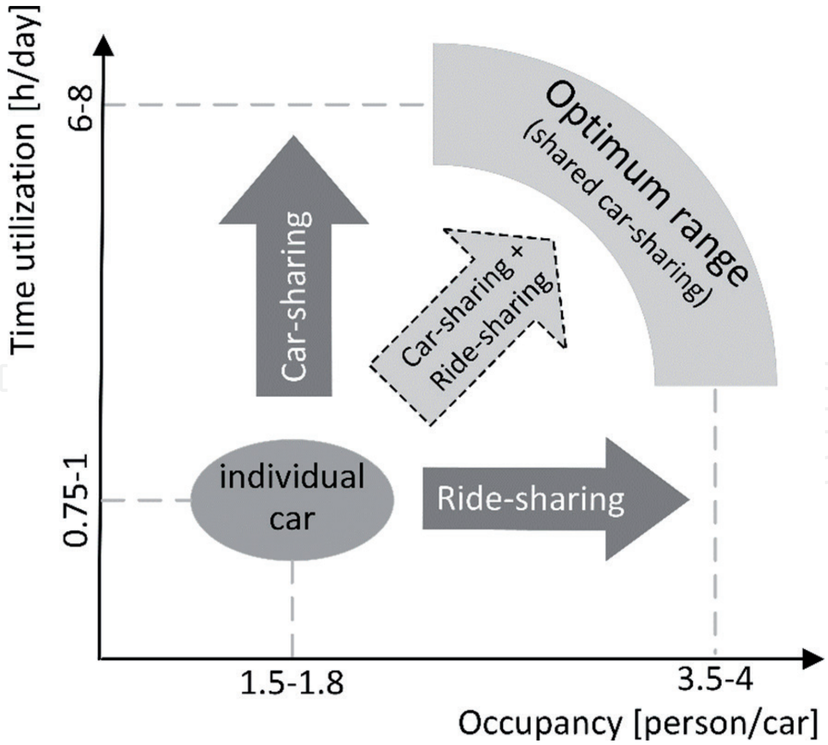

Figure 3.
Enhancement of capacity utilization of individual cars (source: based on [4]).

Travelers' movements should be managed in the network considering these targets. The coordination of passenger flows is represented in **Figure 2** [4].

Shared or transitional modes provide services complementing traditional public transportation. So, new alternatives to individual vehicle use are established. The relevance of that is high as the individual cars are used for only 0.75–1 hour per day and only 1.5–1.8 travelers sit in a car on average during a trip in the European Union. However, the utilization of a vehicle can be enhanced by car-sharing and ride-sharing. The daily utilization of a car can be enhanced to 6–8 hours by car-sharing and the seat capacity utilization to 3.5–4 travelers by ride-sharing. In an ideal case, car-sharing and ride-sharing are to be combined (**Figure 3**), which is a significant potential for the application of AVs.

3. Alteration of mobility services

In the early days, walking and animal-powered (mainly horses) transportation meant the only way of transportation. The individual serve of increasing travel demand was not efficient over a specific volume. Thus, public transportation services were implemented. In an urban environment, the horse-drawn omnibus, later the electric (e.g., tram, subway) and internal combustion engine-powered vehicles (e.g., bus), meant the base of transportation. The use of electric drive-train remained significant in guided public land transportation, namely, electric locomotive, tram, subway (metro), and trolleybuses. Public transportation may significantly contribute to the decrease of fossil fuel dependency [5]. Furthermore, nowadays electric vehicles are getting more and more attention in the field of road transportation.

Because of economic growth, changing lifestyle, and technological development, mobility demand is increasing. Private car ownership and private car use have grown by leaps and grounds. The increasing number of road vehicles made imperative the management of traffic flow. High-quality public transportation and the spread of transitional modes can reverse the tendency. Where the road network, mainly in the European cities with historical urban structure, cannot serve the huge volume of private car use or where the economic growth was not sufficient, the nonmotorized and public transportation become widespread.

At early stages, mobility service providers managed the processes independently without cooperation. In the second half of the twentieth century, many transportation centers have been established to coordinate the public transportation services in urban areas (e.g., common tariff and information system, fee collection). The integration is an expectation from travelers as well.

Innovation in the transportation system is motivated by altering traveler expectations and technical developments [6, 7]. The adoption of novel technologies is a solution to several challenges albeit the shift in technology causes difficulties during the implementation phase and the fears around new technologies are significant. As a result of technology development, the characteristic of vehicles and traffic management alter. Furthermore, the attributes of mobility demand and quality expectations are also altering. The travelers increasingly wish short preparation and travel times, pleasant circumstances during travel, as well as reliable and personalized information services. Intelligent and smart systems are available. Smart systems "know" more than intelligent systems because they are able to learn. The learning ability is programmed into them. With learning ability smart systems can respond not only predetermined situations.

Vehicle automation generates alterations in planning, operational management, and passenger handling functions. The current transportation modes are usually operated under human control, while the back-end functions are more and more automated. In general, automated and autonomous systems are distinguished:

- The automated system is controlled by computers following predetermined, step-by-step rules which were programmed into them, respectively. The algorithms cover potential situations and their consequences.

- The autonomous system is controlled by computers which make individual decisions using cognitive capabilities and learning capacities to manage the situations that have not been known before.

Automated and autonomous vehicles can be considered as moving computers. Several pieces of hardware and software are required for the operation. The operation of these components is simpler if the propulsion of the vehicle is electric. Moreover, the control functions needed for driver-less operation can be adopted easier in an electric vehicle. The main development areas in automotive technology are vehicle control, communication system, validation, and verification of components [8]. In the automotive industry, SAE levels are commonly used for describing only the vehicle control [9].

Several types of public transportation means are already automated, especially in track-based services (e.g., subways). Personal rapid transit (PRT) and group rapid transit (GRT) are relatively new mobility services operated mostly by automated vehicles. The comfortable, exclusive, either feeder or point-to-point services are available in small-scale areas in order not to give up the advantages of individual travel [4].

The entire mobility system is expected to be reshaped due to the widespread use of fully autonomous vehicles. According to the expectations, a high proportion of road vehicles becomes automatized. Currently, the developments of AVs focus on most types of road vehicles such as car, small bus (so-called pod), as well as even air vehicles (drone).

Current transitional modes are merging into a new mode—so-called shared AV. This mode is infocommunication-based, highly personalized, shared, and available via mobile application and provides mostly on-demand or demand-responsive service. Small capacity vehicles, so-called pods, are applied. The seat or trip reservation is mandatory, which supports capacity planning, and so results in efficient transportation. The reservation, especially in urban transportation, requires additional action from the traveler. Since the large one-directional travel demands cannot be served efficiently by any other modes, the high-capacity, arterial public transportation lines remain important in the future too. Different scenarios are made for the type of this mode:

- Door-to-door, shared service [10]
- Feeder service to high-capacity public transportation [11, 12]
- Combination of the previous types [13, 14]

Personalized, flexible, door-to-door service can be provided mostly in rarely built-up areas because of the road capacity limitations. Consequently, in densely populated and highly urbanized areas, feeder service should be provided [13, 15]. The demands can be influenced by the application of dynamic tariff structures. In this way, the traveler is motivated to use the feeder and shared services.

Based on the scenarios, we defined the types of shared AVs:

- Taxi provides individual door-to-door service between any departure and arrival points without sharing the seat capacity.
- Shared taxi provides door-to-door service between any departure and arrival points with sharing of the seat capacity.
- Feeder pod provides feeder service from any departure points in a zone to the stop of an arterial, high-capacity line; transfers are guaranteed by semi-fixed timetable. The operation is symmetric in the opposite direction (from the stop of an arterial line to any arrival points).
- Fixed route pod provides mostly feeder service on fix route. The departure and arrival points are fix stops. It is operated according to fix timetable, but additional departures may be inserted according to current demands [4].

This mode can serve a significant rate of demand derived from individual car use. The individual, private AVs are used only for the most flexible travel purposes. The proportion of soft mobility forms, i.e., walking, and micromobility remain significant in the cases of both individual and shared use. However, the circumstances of soft mode use should be improved, especially in the downtowns.

Future transportation modes are represented in **Figure 4** according to the modality of vehicle use, vehicle owner-operator, and the driver. The modality of the vehicles tends to collective modes due to shared AVs. Furthermore, most of the vehicles are to be owned by a company. The mobility services are managed by an integrated mobility service provider, while vehicles are owned and maintained by either a transportation company or a private person. Especially the smallest capacity vehicles used for taxi and shared taxi service may be owned by a private person. These vehicles can be publicly used when they are not used by the owner (i.e., ride-sourcing service with AVs).

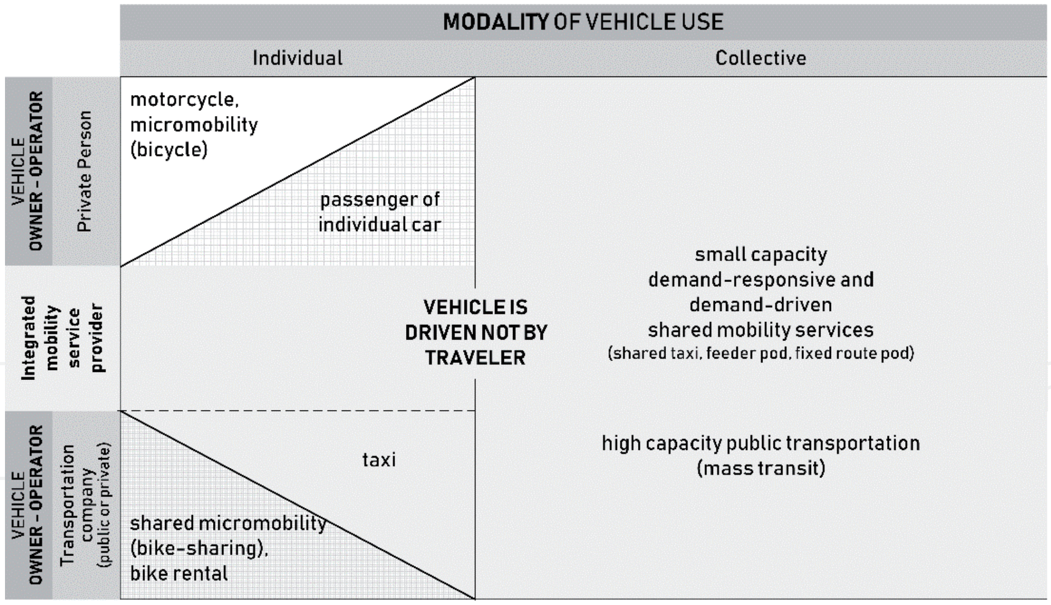

Figure 4.
Classification of future transportation modes.

The future categories of passenger transportation are:

- Individual transportation
  - Nonmotorized: walking and cycling
  - Motorized: individual AV, motorcycle, and micromobility
- Public transportation (mobility services)
  - Small capacity
  - Nonmotorized: bike-sharing
  - Motorized: shared AV, other shared micromobility
  - High capacity (mass transit) based on AVs (e.g., bus, tram) or highly automated vehicle (e.g., subway) [4]

4. Planning principles

The new mobility services require new approaches in planning. Especially, knowledge about mobility services based on AVs is still lacking as vehicle developments are still at an early stage. However, the various and combined service types require novel comprehensive planning and operational methods. Traditional methods [16] should be altered as the consequence of the following factors:

- Complex system architecture (e.g., the vehicle becomes an independent system component, and the number of operational functions is increasing)
- New and unknown technology

- Increasing dynamism of data management

- Altering user preferences and expectations toward a higher quality of service

The traveler needs to learn completely new tasks, and the existing ones should be managed in a different way (e.g., ordering, open/close the vehicle, payment). Because of AVs, the role of human staff can be reduced, and drivers' work regulations are not to be considered anymore. But the lack of staff attendance implies several new challenges both in management (e.g., electric energy charging) and passenger handling (e.g., safety, information). Moreover, the vanishing driver as a job will cause a societal challenge.

Most of the functions can be automated either partially or entirely. The most relevant challenges are revealed in the following functions:

- Real-time demand-capacity coordination

- Planning vehicle runs with and without passengers; furthermore, shared runs are to be introduced

- Customization of mobile application and supplementary services

- Automatic real-time, personalized, and location-based push information provision

- Automatic vehicle charging

In advance mobility services, both data collection and planning functions are supported by software. The planning and operation of the novel, transitional services and shared AVs require a high amount of real-time data. But, as the technology is new, operational data are unavailable. The collection and consideration of user expectations are inevitable. The acceptance and easy adoption of a new service or technology, like AVs, can be significantly enhanced by a highly personalized mobility service considering the user expectations.

Not every traveler group can be served by the new mobility services. For instance, the ride-sourcing services are used by mostly youngers with high education background and for short distance [17]. The acceptability can be measured before the use (as an expectation), whereas the acceptance itself is to be measured after the use (as a revealed preference) [18]. Numerous publications deal with the measurement of expectations toward services based on AVs mostly by stated preference questionnaires [10, 19] or in some cases by revealed preference questionnaires [20, 21]. Measuring the acceptance is rather difficult as bare experience is available. Consequently, the expectations can only be measured according to the stated preferences. But the acceptability is predominantly influenced by the perceived usefulness, expected effort, ease of use, and social influence [12].

In our previous studies [22, 23], we performed a questionnaire survey to reveal user expectations. The main findings were:

- The preferred service type is influenced by motivation and current mode use. The less-flexible (pod-like) types are preferred for less-flexible motivation (e.g., work/school), whereas the flexible (taxi-like) types are more likely preferred for the ad hoc travel motivation (e.g., leisure activity). Current car users prefer flexible types, while public transportation users accept less-flexible service types.

- Higher spatial coverage is expected from the shared AV mode. Namely, the willingness to walk is less in general than in the case of a traditional bus service. But it depends also on the current mode choice preference, the size of the city, and age. Young generations living in big cities and using public transportation have a higher willingness to walk.

- The more flexible the service is, the higher the acceptable fee level is. The younger generation's willingness to pay is higher.

- Mobile application functions that help the use of the mobility service are the most important (ticketing, entitlement checking, fee calculation, display travel-related information).

- Services providing travel-related information, along with the services supporting the use of individual smart devices (free Wi-Fi, chargers), are the most important onboard services.

- Activities which are limited or impossible to do during driving become more popular in the future (looking around, surfing on the Internet/chatting, working).

5. Mobility-as-a-Service

The integration facilitates the establishment of the concept of Mobility-as-a-Service. It provides a wide range of personalized mobility packages in an integrated way that consists of shared, transitional, and mass (public) transportation modes. Instead of tickets and passes, the traveler purchases mobility packages. The mobility package or "monthly plan" consists of rides on various transportation modes (e.g., public transportation, bike-sharing, car-sharing, etc.) provided by several providers. Thus, MaaS establishes the interoperability of transportation subsystems. The combination of travel modes highlights the advantages and eliminates the drawbacks of the various transportation modes. Passenger handling functions (e.g., journey planning, booking, payment) for an entire multimodal journey are operated through a single interface (mainly smartphones). The operational model is presented in **Figure 5**. Traditional MaaS consists of the following modes: bus, tram

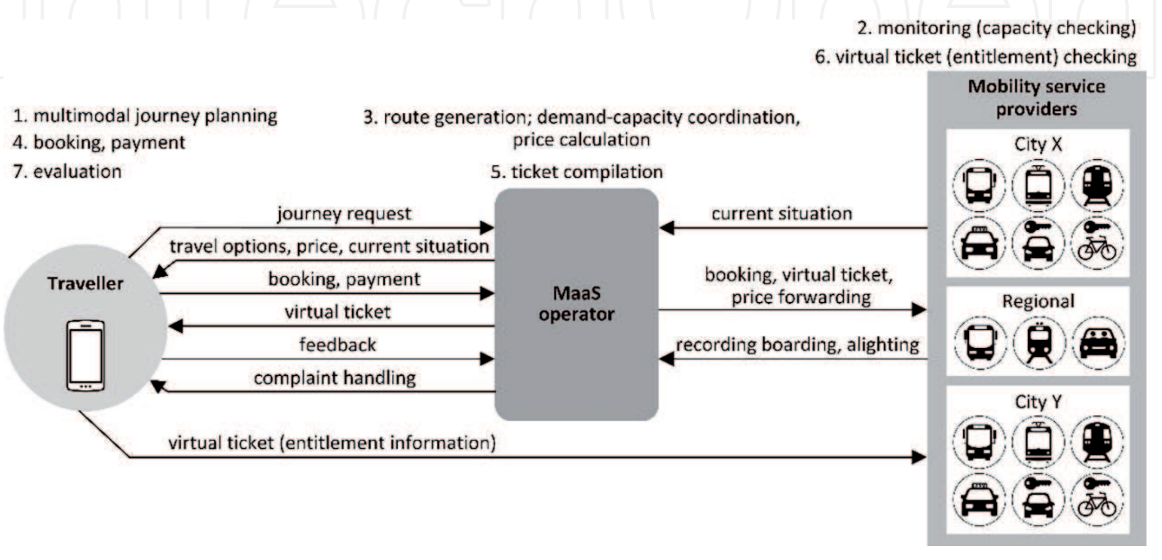

Figure 5.
MaaS operational model (source: [4]).

(light rail), metro (subway), taxi, car-sharing, ride-sharing, and bike-sharing. The operational area of the MaaS is mostly cities, but regional travels can also be managed [4]. The aim is to reach the international and global MaaS operation [24].

The so-called MaaS operator coordinates the processes and connects passengers and mobility service providers. Contracts are made on two levels. On the one hand, a contract is made between the MaaS operator and the traveler when the mobility package is compiled and purchased. On the other hand, a contract is made between the MaaS operator and mobility service provider to permit sub-sale of services. The quality aspects, the minimum level of services, as well as the cooperation-related issues are declared in the contracts (bonus-malus system).

The quality of a mobility service is a complex and partially subjective term which depends on several attributes of the mobility service. Its objectivity is to be enhanced by the application of norms. The quality is an important aspect to facilitate passenger's satisfaction.

The traditional MaaS is defined as a semipublic transportation service. Thus, the quality assessment criteria of both public and private transportation are taken into consideration. Real-time information management among subsystems (e.g., service providers, travelers) is the backbone of this service. The accessibility and availability of transfers are highlighted; the transfer connection both in spatial and temporal senses should be ensured. As shared services are also incorporated, the interior facility of small or medium-sized vehicles may significantly affect traveler's satisfaction (e.g., cleanness).

MaaS can be fully adopted with the application of AVs [24]. The differences between the MaaS provided by traditional and autonomous vehicles are as follows:

- The composition of mobility services (high-capacity public transportation, shared AV, bike-sharing, and other shared micromobility forms)
- Integrated operational control
- Driving
- Passenger handling

The MaaS based on AVs is defined as a public transportation service, where highly automated transportation processes are considered. Namely, the AVs are fully incorporated, and the real-time task coordination process is managed by machine-to-machine components automatically. Service types are highly fused, and the transitional modes are replaced by the service of shared AVs. Assessment criteria of MaaS based on AVs is established on the basis of public transportation [25]. Since MaaS is a smartphone application-based and traveler-centric service, the infocommunication background is tightly related to quality. Travelers interact with "two computers (smartphone and AV)" in real time. Thus, passenger handling functions (e.g., journey planning, booking, payment), as well as seat reservation function, are to be assessed as the specialties of this service. In the case of MaaS based on AVs, the aim of MaaS operator is to enhance the quality, while sustainability is attained in all senses at.

6. Impacts of alteration

Reshaped urban mobility implies several impacts. Due to shared and demand-driven services, it is expected that the individual car use will decrease. However, the change in the travelers' mindset is needed. In an urban area, individual car use and car ownership are to be eliminated. Necessarily, efficient public transportation and introduction of shared and transitional transportation modes are required. In developed countries, the intention to own a car is decreasing among the younger generation.

Significant benefits can be gained by dynamic assignment of shared vehicles for different service types [26]. The benefits are relevant for passengers (e.g., reduction of travel time and fee) and operators (enhanced utilization rate). However, the utilization of shared services is not efficient without adequate management. For instance, the capacity utilization of a taxi service is not efficient without seat-sharing [27]. The mileage of taxis can be reduced by 40% by seat-sharing [28].

Moreover, if shared, demand-driven services are too convenient, the share of high-capacity public transportation decreases, which may cause further problems (e.g., increasing traffic jams). For instance, at least half of the ride-sourcing trips replace traditional public transportation trips [17].

The application of AVs has impacts on society and the environment too. The length of trips is expected to grow as travel time is spent in a more efficient and pleasant manner. In this way, daily commuting distance can be even longer. Furthermore, travel time can be reduced as a result of better drivability of the vehicles and advanced traffic control. Vehicle design and passenger compartment also alter. The individual total utility of travel increases, because onboard activities may replace activities performed at home or the workplace. All in all, the number of travels is expected to increase.

However, individual car use decreases by the introduction of a flexible shared AV service because similar service quality can be provided as by an individual car. Current car users' willingness to shift is the highest, as bikers' and pedestrians' willingness to shift are the lowest according to our previous study [29]. The number of cars decreases as less vehicle is enough to meet the needs. Furthermore, the capacity utilization and useful mileage of the vehicles increase because of the shared use. However, the number and length of empty runs may increase due to dissimilar pickup and drop-off points of passengers.

The vehicles communicate with each other, with the infrastructure and with other road users. Consequently:

- The number of road accident decreases [30], and traffic safety increases.
- Traffic parameters alter, for instance, smaller headway and higher speed.
- Traffic control alters [31], for instance, less traffic sign is enough, but a complete replacement of them is not expected as they are needed by soft mobility users.

The public places in cities are utilized in a different way which causes a paradigm shift in urban design as well. The number and extension of road infrastructure elements are also expected to be altered. For instance, less parking lots are enough. Accordingly, the available space for pedestrians and micromobility users or other, non-transportation-related functions (e.g., green areas) can be increased. The time base of road infrastructure elements is to be shared between the functions:

- Shared parking lots:
  - At night or daytime, residents or shared AVs park and recharge.
  - In daytime shared AVs use them as virtual stop.

    - In dedicated time intervals, freight AVs serving neighborhood shops, restaurants, etc. park and recharge during loading.

- Shared traffic lanes: in the peak hours for moving traffic, in the off-peak hours for parking

Though the AVs may serve any point, they cannot stop "anywhere." Therefore, allocation of virtual stops is needed. Virtual stops are points where passengers can board and alight an AV in a safe way and the traffic is not hindered. Virtual stops can be established without any special infrastructure.

The energy consumption becomes more efficient as a result of energy-efficient vehicle control. Thus, the environmental impact of transportation is also reduced. Pollution decreases further if electric and renewable energy sources are applied.

The traveler groups alter as well. Current car drivers become passengers. Demand-driven mobility services provide better spatial coverage and time availability as they usually serve door-to-door rides on demand. Accordingly, some pedestrians become also passengers as the use of a demand-driven service can be faster and more comfortable than walking. The small AVs may be also considered as an accessory of a building. While the elevators support the vertical movements, the small AVs connect the locations with horizontal movements. The travelers can enter the building with them (e.g., during shopping). Thus, the concept of smart vehicle and smart mobility is related to the concept of smart home or building, and from a wider perspective, these all are part of the smart city concept. However, all in all, the share of pedestrians and micromobility users is expected to increase as soft mobility modes are promoted, especially in urban areas (e.g., pedestrian zone). Accordingly, both soft mobility modes and the shared use of AVs as a feeder service are needed in order to avoid the significant increment of motorized road traffic.

7. Conclusion

In this chapter, reshaping urban mobility was discussed in a transportation engineering point of view with a special focus on automation. The main contribution of the chapter was the description of transportation modes and current mobility services, as well as the detailing alteration in urban mobility. Moreover, planning principles of such mobility services and MaaS as a concept was overviewed, and the impacts of alteration were summarized.

The border between the individual and public transportation modes is blurring. Novel shared and on-demand, so-called transitional transportation modes are spreading in cities which can provide similar service level as individual car use but in a more efficient way as either the vehicle in time or the seats are shared.

New mobility services based on AVs are expected soon. We found that the transitional transportation modes and, even more, most of the individual car use can be replaced by a new, shared, demand-driven mobility service based on small capacity AVs which is accessible only with advance ordering via a mobile application. However, we highlighted that as the capacity of the built infrastructure is limited, the travel demands can be served efficiently only by shared and feeder mobility services. Additionally, promotion of walking, public transportation, and/or micromobility use is also required. Mobility-as-a-Service concept contributes to achieving these aims. Moreover, the shared use of vehicles causes significant alteration in cities, e.g., the function of public places alters.

Since the current shared services are novel, and the mobility services based on AVs are at the very early stage, only assumptions can be made about the impacts. Considering the user expectations during the planning of these services is inevitable. In that way, the acceptance and adoption of new services can be facilitated.

Possible future intentions are to be the elaboration of novel, complex evaluation and comparison methods for mobility services. The evaluation covers service quality, flexibility, features of integrity and automation, as well as customization. Furthermore, planning and operational methods of mobility services based on AVs are to be developed, and travelers' expectations are to be analyzed.

Acknowledgements

The research reported in this chapter was supported by the Higher Education Excellence Program of the Ministry of Human Capacities in the frame of Artificial Intelligence research area of the Budapest University of Technology and Economics (BME FIKP-MI/FM).

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