Mobilty Services – Does Individual Optimization Scale Out?

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***Abstract*— Mobility in industrialized nations is characterized by individual transport. Especially since the 50`s of the last century, individual mobility is based on automobility. The age of automobility still influences and shapes the infrastructure development of our cities. While the model of a car-friendly city has evolved a lot, it does not seem to be capable to generate efficient means of transportation. This becomes worse in emerging metropolitan areas with large growth rates. Besides congestion, pollution is a main issue, especially in fast growing metropolitan areas. Nowadays, a lot of new mobility services are offered through the internet. Besides mobility based on cars, these services incorporate intermodal mobility, as well as third domain offers, which may reduce our individual mobility. In this article, we will provide an overview of such services and derive insights about their possible impact.**

Keywords - Mobility; intermodal mobility; sharing economy; e-services

I. INTRODUCTION

Growth of population and increased traffic because of both individual mobility as well as cargo logistics lead to congestion and pollution [1]–[3]. Metropolitan areas, especially, suffer from those effects. A large amount of these issues are caused by automobility. During the 20th century the model of a car-friendly city has been developed and evolved. Especially in industrialized countries, cars dominate infrastructure development. Areas with more than 800.000 inhabitants suffer from congestion peaks as the TomTom Traffic Index [4] indicates. The congestion level (CL) is measured as the increase in overall travel time compared to an uncongested situation. In general, the congestion level (CL) is considerably high, however, the evening peaks (EP) are typically the worst time to commute using a car (compare Tab. 1). Hence, traffic planning and management is usually focused on road planning and construction.

The public sector seeks to implement and promote alternative modes of transport. Public transport for instance is usually subsidized at community, regional or national level. In some countries, e.g., United Kingdom, public-private-partnerships are concluded to operate public transport. Sometimes regulations are made to support alternative transport modes. One famous and successful example is the London congestion charge [5]. It is observed that the charge reduces traffic, which is caused by cars by 14% and congestion, is reduced by 30% [5].

Another example of support for other modes of transport is the regulations that we put in place. In late 1950's, for instance, the ministry of transport in Germany tried to support rail based cargo by reducing maximum size of trucks and trailers. This turned out to be ineffective since manufacturers developed a new type of truck – a smaller driving cab allowed to enlarge loading. Unquestionably, there are a lot of examples where the public sector tried to or successfully influenced the choice of transportation mode of people. On the other hand, looking at individual mobility, costs associated with buying and operating a car decreased, compared to average wage and hence promoted ownership and usage of cars. In this article logistics represent an import part of traffic and we will focus on individual mobility. The remainder of this article is structured as follows: in section 2 we will present some statistics with focus on usage and change on transport modes. Furthermore, we will discuss related work on reduction of traffic congestion. Challenges which arise from these observations will be discussed in section 3. Section 4 deals with services that promise further shift in transport utilization and hence, might be able to improve the overall situation. Finally, section 5 of this article concludes with findings and an outlook on future work.

II. RELATED WORK

In this section we will analyse statistical traffic data and discuss related work. The next subsection contains statistical data about traffic development and mobility behavior of people. Especially, mono modal car utilization and increased intermodal travel behavior. The second sub sections will present typical approaches to reduce congestion levels.

A. A statistical view on traffic

Areas with high economic growth rates, often in developing countries, suffer most of the traffic congestion (see Tab. 1 and [1]). Typically, this is related to a significant increase in passenger car use (e.g., as recorded in Turkey). In contrast, the relative importance of the passenger car as main mode of transport in passenger traffic decreased in 13 member states

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of the EU. This trend is led by Italy (in the period from 2002 to 2012 passenger car share fell by 4.4 percentage points) followed by Luxembourg (2.7 points) and the United Kingdom (2.4 points) and can also be observed in three of the largest EU Member States - Germany, Spain and France. Average numbers of the ten best EU countries are shown in Fig. 1 (also see [6]).

In contrast to some decades ago, people are less attracted by a single mode of transport. While cars are still dominant we observe changes, and growth in alternative modes of transport (e.g., rail and bicycle). Both changes are often related to sharing concepts and internet based mobility services. As shown in Fig. 2, especially young people are increasingly utilizing all modes of transportation [7]. They reveal multimodal travel behavior. Multimodal travel behavior is revealed when people switch their main mode of transport for longer trips (e.g., different trips in the course of one week). Similarly, intermodal travel behavior is becoming more famous. An intermodal trip can be defined as a combination of several transportation modes during a single trip, e.g., a trip with public transport in combination with bicycle or car. Furthermore, different modes of transport seem to be adopted in respect to specific situations (context of travel and personal preferences).

TABLE 1: CONGESTION LEVEL (CL) - TOP 15 CITIES [4]

Rank	City	CL	+/-	MP	EP
1	Mexico City (MEX)	59%	4%	97%	94%
2	Bangkok (THA)	57%	0%	85%	114%
3	Łódź (PL)	54%	-2%	72%	98%
4	Istanbul (TUR)	50%	-8%	62%	94%
5	Rio de Janeiro (BRA)	47%	-4%	66%	79%
6	Moscow (RUS)	44%	-6%	71%	91%
7	Bucharest (ROU)	43%	2%	83%	87%
8	Salvador (BRA)	43%	-3%	67%	74%
9	Recife (BRA)	43%	-2%	72%	75%
10	Chengdu (CHN)	41%	5%	73%	81%
11	Palermo (ITA)	41%	-1%	62%	66%
12	Los Angeles (USA)	41%	2%	60%	81%
13	Saint Petersburg (RU	40%	-4%	64%	88%
14	Belfast (GBR)	40%	1%	82%	86%
15	Dublin (IRL)	40%	2%	85%	81%

Looking at statistical data available for Europe, it seems that reduction of mono modal car utilization and increased intermodal travel behavior is also related to age and internet affinity. According to Eurostat [6], internet based services also experience higher growth rates in countries which are successful in promoting alternative modes of transport. This, especially, is interesting regarding forecasts of overall modal development. At this time, we know that younger people are more likely to become intermodal travelers. While there is a correlation to adoption of sharing concepts and internet usage. Nevertheless, today it is still not clear if there is also a causal connection. Thus, an open question is, if these people change their behavior once they become older or if they keep their attitude as it is – another possible causal connection might be the level of income or other personal preferences which change with age.

Figure 1: Modal split - Top 10 EU countries in train growth [6]

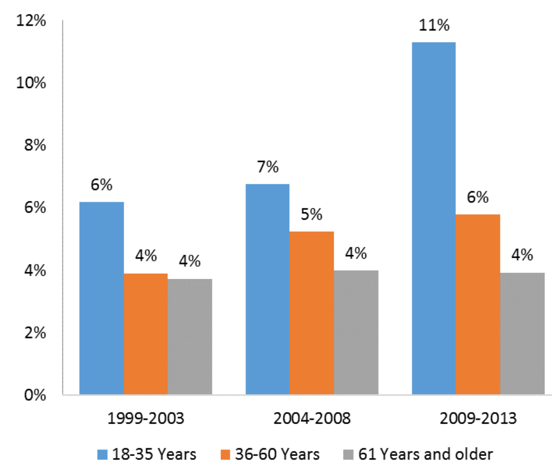

Figure 2: Share of people with multimodal transport behavior

B. *Approaches taken to improve traffic flow*

Different approaches have been taken to reduce traffic congestion. This incorporates basically three distinct ideas: (1) reducing congestion by upgrading infrastructure, (2) avoiding congestion based on intelligent routing and (3) reducing congestion through alternative services. The latter includes the idea of utilizing different transportation modes and the concept of services to reduce the need for individual mobility.

In this case, changes in infrastructure belong to the field of urban or regional traffic planning and management. Within the last decades a lot of research based on predictive analytics and methods of operations research has been conducted to improve traffic planning. Traffic models to support infrastructure planning characteristically recognize individual behavior (including when, where and why a user will travel). In a second step individual behavior is aggregated to an overall network behavior which can provide information for sound decisions concerning management, control, and improvement of traffic infrastructure [8], [9]. On behalf of the society, these calculations are utilized to make decisions for public investments. Hence, traffic planning is typically based on a hierarchical process [8], [10], where decisions made by the public sector seek improvements of the overall performance of the traffic network. Since many people travel by car, a lot of these efforts lead to road construction.

Since people tend to make their choice with regards to activity, route, travel mode, origin and destination of their travel and of course personal preferences, a lot of research has been conducted about route optimization [8]. This area of optimization research does not focus on individual mobility, but rather on cargo transport. For cargo and larger fleets, route optimization can save time and cost for carriers. Of course, if routes are optimal in terms of fuel consumption, the carbon dioxide emission is also reduced. Intelligent routing has been under research since almost 50 years. It includes the idea of re-routing based on the current traffic situation and pre-trip planning based on traffic prediction. The presumption for route guidance based on real-time traffic information is that traffic congestion can be reduced by intelligent routing [11]. A lot of different algorithms and types of presentation have been tested during the last decades [12]. This development was initiated by large metropolitan areas during 60's and early 70's, which began to develop and test technologies for traffic surveillance and real-time information dissemination. Nowadays the transportation development is driven by information based on Wi-Fi networks, smartphones and other GPS devices (e.g., car integrated systems) which are utilized by modern information systems and their operators – here navigation, e.g., TomTom or Google just to name a few of them [13]–[15]. It has been agreed that there is a saturation effect once information is used by a certain amount of users [16]. Therefore, routing algorithms have also been extended with parking models [17], [18] and ad-hoc mode switches [19]–[22]. Alongside several approaches have been suggested in logistics, including routing, as well as alternative transportation modes [20], [23]–[25].

Information can cause drivers to change departure times in such a way that influences congestion. Besides intelligent routing and information systems, there is another psychological aspect. Users tend to adopt suggestions once their preferences are met. This includes the design of user interface, transportation mode (in case of ad-hoc switch), cost, approximate delay, and driver comfort [12].

III. Challenges and Motivation

On one hand, in many metropolitan areas people seem to accept that they have to deal with congestion during their daily routine. Nevertheless, with high growth rates this situation even turns worse. On the other hand, looking at current growth rates of metropolitan areas and reports on traffic congestion as discussed above, it seems obvious that new solutions are needed to improve the overall mobility situation. A couple of different challenges can be derived from these issues, which apply for regions all over the globe. Amongst others, four important challenges to overcome the current problems are:

1. Service offerings to reduce mobility demand
2. Congestion level reduction
3. Options of traffic mode enlargement
4. Carbon dioxide emission reduction

If services reduce the need to travel, this would be probably the easiest solution to reduce congestion and pollution. Surrounded by current discussions on industry 4.0 and digitalization, services could transform work and life in ways which reduce travel activities because of meetings or even prevent daily commuting. Some services might just reverse current principles, so that users receive goods instead of actively obtaining them [20], [26]. Others, e.g., video conferencing or telework, promise to reduce mobility in general. The latter seems promising, but despite further development in technology, the effects in recent years where considerably low. Hence, and even in car-characterized metropolitan areas, new and alternative mobility services can be observed currently. These services are often related to sharing concepts where people either share their own goods (in this case, usually a car) with others or a commercial provider offers goods to share. This idea gains an increasing popularity in recent years.

IV. Mobility Services

Looking at the service level, it can be observed that mobility services are offered for various kinds of purposes. Within this article, we intend to have a closer look at one very promising kind, the so called *mobility services* (mobility-as-a-service or MaaS) which have been proposed and promoted as approach to achieve more sustainable transportation [27]. We strive to shed light in the current market situation, especially reachability and possible impacts are part of our exploration. MaaS are typically associated with a shift away from personally owned towards mobility solutions consumed as a service. To enact MaaS, services are currently offered by public and private transportation providers often employing a unified gateway that creates and manages trips. Opposed to subscriptions (e.g., a monthly fee), users can often pay per use, e.g., per trip based on time and distance. MaaS is offered for both people and goods. For individual mobility it often encompasses individual preferences which are considered in offers and planning of trips. Currently, mobility service offers are quite diversified and often related to sharing economy, examples are ridesharing, car sharing, carpooling, bike sharing, as well as on-demand pop-up bus services. In this article, mobility services of the following categories are further analyzed: car sharing, ridesharing, carpooling and multimodal trip planning. We will provide a definition for all of these service categories.

Carsharing is an umbrella term that covers multiple types of sharing. Carsharing (US) or car clubs (UK) is a model of car rental where people rent cars for short periods of time, often by the hour. They are attractive to customers who only occasional use a vehicle, as well as those who like to have occasional access to vehicles of a different type than they use day-to-day. The provider renting the vehicle may be a commercial business or the users may be organized as a company, public agency, cooperative, or ad hoc grouping. In consequence, car sharing includes B2B, B2C and C2C offerings including informal peer-to-peer (P2P) arrangements. Cars may be available at fixed stations (dedicated parking spots) or on a free-floating basis, which allows users to drop their vehicle at any legal spot within a defined zone. Currently, car sharing is taking hold in large urban areas. The global usage of car sharing is rapidly growing in recent years. As measured by number of vehicles, the growth rate was over 800% over a period of eight years (2006 to 2014). As measured in number of users, the growth was even 1400% in the same period [28]. More recent press releases seem to confirm this development. The largest markets currently are the Asia-Pacific region (including Australia, China, Hong Kong, Japan, Malaysia, New Zealand, Singapore, South Korea, and Taiwan), Europe (including Turkey and Russia) and North America (including Canada and the United States). Besides classic combustion engines, more and more electrically powered cars are being operated by carsharing providers.

Ridesharing, as second type of service, involves being driven rather than driving, and has existed on an informal basis for as long as there have been cars. Ridesharing has evolved into organized taxi services and more recently, into new models such as offered by companies like Uber or Lyft. *Carpooling* is the best way of reducing costs by sharing a car, which are divided among the occupants, and also reducing the number of vehicles on the road, with the corresponding reduction in pollution, consumption, accidents and parking problems [18], [29]. *Multimodal trip planning* services are smart travel assistance tools which provide pre- and on-trip travel planning. Information provided to the customer is usually planning data of public transport often enriched with real-time traffic information. The services offer information such as road network and traffic conditions. Data is typically collected from various mobility providers and often is provided with real-time precision [30].

We analyzed 51 mobility services within these categories. We included those services which have emerged in the last five years and could sustain on the mobility market. It is notable that most services somehow incorporate sharing concepts. We are classifying these mobility services into the following groups:

- *Peer-to-peer sharing services (P2P)*: private peer-to-peer arrangements to rent private owned vehicles. Typically, a mobility provider offers a marketplace.
- *Sharing service providers* (*B2C*): professional mobility providers offer (rental) vehicles in station-based or free-floating models.
- *Ridesharing services (B2C)*: professional mobility providers act as a broker to provide driving services with private and business cars.
- *Carpooling services (P2P)*: Individuals are sharing a car together. Mobility providers offer a marketplace.
- *Multimodal trip planning services (B2C)*: Mobility providers are providing trip planning by offering multimodal mobility.

The analyzed mobility services are characterized by different types of services (see Tab. 1). A huge potential is given by business car rental services (32% of analyzed services). Bike and car sharing services experience huge growth rate followed by private car rental services (18%) and private car lifts (13%). Most of these mobility services can be requested instantly (55%) and are also provided as planned request (45%). 80% of the offered mobility services are single transportation mode, 20% are multi transportation mode.

Currently, the majority of multimodal services are information only services. This means they provide information but booking is not an option. Looking at geography, most of the mobility services we analyzed are provided in Germany only (25%), followed by global services and in Europe operating services (20%) and those offered in US (14%).

V. Conclusion

Recently, it is noteworthy that a lot of mobility services have been placed on the market. It is also expected that this market will be consolidated and may reach saturation. This also depends on viable or publicly subsidized (e.g., bike sharing in Germany) business models. Looking at the identified categories, various peer-to-peer sharing services with similar mobility service offerings which include acting as agency for private cars, providing a marketplace, assurance services and personal user reviews can be observed.

TABLE 2: MOBILITY SERVICES

		Mobility service	Service Type	Belongs to	Service range	Distance	Information
Peer-to-Peer car sharing services		getaround	private car sharing		US	s,m,l	200.000 users
		turo	private car sharing		US	s,m,l	
		drivy	private car sharing		Europe	s,m,l	38.000 cars
		tamyca	private car sharing		Germany	s,m,l	
		carunity	private car sharing	Opel (operated by	Germany	s,m,l	
		SnappCar	private car sharing		Europe	s,m,l	
		Ryde	private car sharing		Asia	s,m,l	
Sharing service providers	Car	Mavendrive	car sharing		US	s,m,l	
		Autolib	e-car sharing		France	s,m,l	3.000 electric cars, 6.600 charging stations
		Orix	car sharing		Japan	s,m,l	
		Park24	car sharing		Japan	s,m,l	
		eCar	car sharing	Citroen	Germany	s,m,l	250 e-cars
		EVCARD	e-car sharing		China	s,m,l	1.500 e-cars
		Car2Go	car & e-car sharing	Daimler	Global	s,m,l	14.500 cars, 1.600 e-cars, 1.900.000 users
		mobility	car sharing		Switzerland	s,m,l	
		finkster	car sharing	Deutsche Bahn	Europe	s,m,l	6.000 cars, 300.000 users
		stadtmobil	car & e-car sharing		Germany	s,m,l	4.000 cars, 52.000 users
		zipcar	car sharing	AVIS	Global	s,m,l	
		DriveNow	car & e-car sharing	BMW, SIXT	Europe	s,m,l	4.700 cars, 500.000 users
		ReachNow	car & e-car sharing	BMW	US	s,m,l	
		cambio carsharing	car & e-car sharing		Europe	s,m,l	4.600 cars, 79.600 users
	Scooter	eMio	e-scooter		Germany	s,m	
		COUP	e-scooter		Germany	s,m	
		Yugo	scooter		Spain	s,m	
		motit	scooter		Europe	s,m	
		scoo.me	scooter		Germany	s,m	
		scoot	scooter		US	s,m	
	Bike	nextbike	bicycle		Germany	s	
		Call a Bike	bicycle	Deutsche Bahn	Germany	s	
		MeinRad	bicycle		Germany	s	
		MVG Rad	bicycle		Germany	s	1.200 bikes
		bikesurf	bicycle		Global	s	
		BbikeMi	bicycle		Italy	s	
		Bycyklen	bicycle		Danemark	s	
Ridesharing services		uber	marketplace		Global	s,m,(l)	160.000 drivers
		taxi magic / curb	cab marketplace		US	s,m,(l)	50.000 taxis, 100.000 drivers, 65 cities
		mytaxi	cab marketplace	Daimler	Germany	s,m,(l)	45.000 taxis
		GroundLink	limousine marketplace		Global	s,m,(l)	45.000 cars
Carpooling services		lyft	car pool marketplace		Global	m,l	collecting Starbucks points
		bla bla car	car pool marketplace		Europe	m,l	
		karzoo	car pool marketplace		Europe	m,l	
		mitfahren	car pool marketplace		Europe	m,l	
		e-carpooling	car pool marketplace		Switzerland	m,l	
		drive2day	car & train pool marketplace		Europe	m,l	shared train rides
		via	car pool marketplace		US	m,l	
Multimodal services		Ridescout / Moovel	mobility information platform	Daimler	Global	s,m,l	
		SBB Trip Planner	mobility information platform	SBB	Switzerland	m,l	
		TripIt	mobility information platform	SAP	Global	l	110 countries
		TripCase	mobility information platform		Global	l	30 Mio trips, 40 airlines
		WorldMate	mobility information platform		Global	l	
		Qixxit	mobility information platform	Deutsche Bahn	Germany	s,m,l	meta service, partial ticket booking

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Sharing service providers usually offer a single transport mode and thus, differ into bike, scooter and car sharing. While a lot of services offer the same concept, the saturation of the consumer demand is not reached yet. Additionally, and still in growth stage with rising demand, car sharing services are also provided or supported by major car manufacturers, e.g., Daimler (Car2Go) or BMW (DriveNow, ReachNow). Another car sharing service, flinkster, is even operated by Deutsche Bahn (German railroad provider). The traditional sharing business model (B2C) is difficult to scale geographically, especially to neighborhoods with lower population densities. Operators must accept fixed costs for purchase or lease of vehicles in the fleet. In contrast to that, peer-to-peer (P2P) sharing allows to rent pre-existing vehicles on a short-term basis. Most privately owned vehicles sit idle more than 90% of the day. Thus, P2P carsharing alleviates upfront costs and is more economically consistent with lower-density neighborhoods than traditional sharing. Currently carsharing services are a niche transportation option for certain demographic groups. Today, typical participants live in urban neighborhoods with medium to high household densities [31]. As a result, P2P carsharing provides greater potential for car accessibility than traditional carsharing does [32].

Unquestionable, the congestion-relief potential of sharing rises with the number of services and users. While currently bike sharing possesses even higher growth rates, carsharing has the potential to reduce the number of cars on the road significantly [31]. Carsharing business models have evolved to include both point-to-point and round-trip systems, while parking options have expanded to include both on-street and dedicated spaces in an increasing number of new developments so carsharing networks become denser and more ubiquitous. The shift in consumer preferences will further broaden the appeal of sharing.

Looking at customer level, multimodal trip planning services hold a great potential, but currently they suffer from missing booking opportunities and thus, do not unfold their full potential [22]. These services are capable to integrate all other service types. To reach this they need to be more than just information services. An interesting and promising development are multimodal mobility services supported by public transportation providers (e.g. Deutsche Bahn and SBB) in extension to their traditional business model. In summary, we identified four aspects that influence mobility services:

(1) The mobility behavior of users is changing

(2) The offer of mobility services is increasing

(3) Catalyzer effect – traditional mobility providers are joining the services market

(4) Products and services are converging

The demand for mobility services is growing since progressively, more users are using the advantage of new service types for flexible mobility instead of using individual private or public transportation modes. The amount of mobility providers is still increasing and many providers are on the market offering the same services. So far and due to market growth, this competition did not lead to a consolidation of providers yet. To participate in growth rates traditional public transportation providers and car manufacturers also enter the market for new mobility services. Instead of just selling products, cars are evolving to product service systems.

VI. Outlook

A lot of research and experimentation has been conducted to reduce traffic congestion. Nevertheless congestion is still a big issue around the globe. In consequence, numerous techniques have been applied to tackle this problem. A very promising one is coming up with combined ubiquity of internet connection and mobility e-services. As discussed these services include pre- and on-trip planning, real-time information, ticketing, mode-switch, and unquestionably re-routing. Currently services which enact intermodal mobility and just in time ticketing experience high growth rates.

While today a lot of different services are present we expect a future market consolidation. We could already observe consolidation in the long distance bus market, as well as in carsharing services. More recent service types, such as electric recharging stations or multimodal information and ticketing services, are still uprising and plenty of new providers urge to market. As next steps, we plan to collect more data on services. We intend to look into two different aspects: usage (individual behavior and preferences) and markets. Regarding market development, we plan to broaden our services analysis, especially with an extended analysis of the Asian market. This will provide insights on success factors of services, as well as on people's behavior. Furthermore, we plan to observe the development of intermodal behavior and services market development over a longer period of time. Therefore, we intend to establish an open database to store and to provide information on mobility services. Besides individual mobility, which is our main interest, we consider to broaden this to logistic services.

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