Smart Transportation – Facing Challenges in Future Traffic Systems

David Gollasch
Technische Universität Dresden
01062 Dresden, Germany
david.gollasch@tu-dresden.de

ABSTRACT

Smart transportation in context of the idea of a smart city is an umbrella term for attempts on finding solutions for future mobility challenges in urban areas. This paper gives an overview of current research findings according to the arising challenges. Especially the fields of smart cars, smart traffic controlling by means of sensor-based networks and bike sharing as an alternative way of travel are of special interest here. To give a deeper insight in the named areas, three concrete ideas – one for each of the fields – will be presented in more detail: a solution for the increasing parking space problem for cars, a feasible camera-based sensing network infrastructure and a concept to answer the question of where to create bike sharing spots in an urban environment that meets the actual demand.

Keywords

Smart City, Smart Transportation, Smart Traffic, Smart Cars, Bike Sharing, Sensor-Based Networks, Smart Traffic Monitoring

1. INTRODUCTION

The ongoing growth of human population worldwide and the urbanization leads to a general growth in public infrastructure. Just to give some numbers referring London as an example: From 1800 to 1911, London became the largest city on earth by growing from about 1 Million inhabitants to about 7 Million. Nowadays, London has a population of about 8 Million inhabitants and does not lead the list of the cities with the largest population anymore. [12] This is a tremendous growth and unchallengeable trend that today's society has to cope with urgently.

Mark Shepard describes the *sentient city* as "one that is able to hear and feel things happening within it, yet doesn't necessarily know anything in particular about them" (ref. [1]). The artificial term *smart city* has no clear definition, but is generally used to describe ideas that tackle the upcoming challenges regarding an increasing load on public infrastructure by means of modern information technology. This can be seen as part of the sentient city or an approach to it. The more general term *smart planet* that is dominated by IBM can be seen as a supplement to smart cities. [16]

Su et al. [16] elaborates eight areas as part of the smart city idea:

- Wireless city
- Smart home
- Green city
- Smart tourism
- *Smart transportation*
- Smart public service
- Smart urban management
- Smart medical treatment

This paper focusses on the above highlighted area of *smart transportation*, because mobility is a major challenge in today's society and surely will not decrease in importance tomorrow. Additionally, mobility influences many other mentioned areas of smart cities such as environmental friendliness and tourism.

The rest of the paper is structured as follows. Section 2 will give an overview of the challenges regarding urban transportation, including mobility and traffic, that are expected to arise in the future. The main part of this paper is located in Section 3 which consists of attempts to tackle the challenges presented in Section 2. Furthermore, these attempts focus in more detail on concepts for cars (smart cars), sensor-bases safety (smart traffic controlling) and bike sharing concepts (smart bikes). Section 4 finalizes this paper by giving a brief summary and outlook.

2. ARISING CHALLENGES IN FUTURE TRANSPORT SYSTEMS

To get to the *smart city*, Su et al. [16] introduced the following five major challenges to face:

Management, Integration and Release of Massive Urban Spatial-temporal Data. The current way of gathering multi-source information in the urban environment is not appropriate for tomorrow's needs that require the ability to serve "real-time updates, historical reconstruction and future prediction" as it is too static and less dynamic.

Large-scale Space-time information and efficient services. The amount of information that has to be managed in the future is enormous. Furthermore, there will be structured data, like temperature or geographical coordinates, as well as unstructured data, such as audio-visual media files. This directly leads to the necessity of having efficient data storage and management solutions.

Model of Heterogeneous Sensor Data and Expression of the Internet of Things. As the Internet of Things is an important part of the smart city approach, it is necessary to build a model that can structure and order the information distributed by sensors of different kind, such as location, time and status-related data. Additionally, the efficient observation of this data to react on specific events is a challenge.

Technology of Intelligent Analysis and Decision Support. Based on the data the smart city collects, intelligent mechanisms are required that enable an efficient analysis of this data and that allow deriving good decisions in consequence.

Sound Information Service and Shared policy mechanism and legal protection. Collecting, analyzing and reacting on data always leads to legal questions that need to be answered. Hence, a sound legal situation is required that offers a high level of data security and protection on the one side and does not hinder valuable and useful innovations on the other side.

These major challenges can be interpreted in a way that it is important to improve the process of gathering information and analyzing them as well as deriving better and more dynamic decisions out of these information. Based on that and because this paper focusses on smart transportation, several researchers identified more concrete challenges to cope with in the future regarding transportation and traffic.

The *individual motorized traffic (i.e. cars)* is a challenging field of tomorrow's urban transportation. Cars are becoming increasingly complex from a technological point of view. To tackle this, intelligent car control systems are demanded (Nazmul Hasan et al. [13] and Ferreira et al. [7] are working on that topic). As the traffic load in urban areas will increase and urban environments offer potentially dangerous or at least difficult situations, passenger safety and security is an issue of higher interest (Shaikh and Kate [14] are working in that field). A second issue regarding the increasing traffic load in urban areas is the – already today well-known – problem of finding affordable parking space (Circella [5] and Gopalan et al. [9] are working on that problem).

The safety (and security) issue is not only related to cars, but to all individuals participating in road traffic. Hence, there is a demand for *smart traffic control systems and/or sensor-based networks.* Regarding the safety issue, Karpinski et al. [10] and Barba et al. [2] published relevant findings. Mechanisms for dynamic traffic monitoring and controlling to cope with high transportation infrastructure load are tackled by Kostakos et al. [11] and Calderoni et al. [3] in their published findings.

To address the problem of too many cars in urban environments, it is useful to offer convincing alternatives. Public transportation is one common alternative. Another upcoming approach is *bike sharing* (also referred to as *smart bikes*). This approach derives two major challenges: On the one hand, there is the challenge to convince people to use bike sharing offerings instead of driving by car. This has been addressed by DeMaio and Gifford [6] and different concrete case studies, such as one by Castillo-Manzano and Sánchez-Braza [4] or one by Zhao et al. [18]. On the other hand, it is a challenge to reasonably address traffic load problems by means of bike sharing in an efficient way. Therefore, Vogel et al. [17] address bike-sharing-related activity tracking in their findings, and García-Palomares et al. [8] worked on ways to optimize the process of determining the right bike sharing locations which is the crucial interface for potential users as it allows accessing those bike sharing services.

All named issues/challenges are directly linked to the five above mentioned general challenges by Su et al. [16] as their solutions heavily relate on an efficient handling of data that needs to be captured by sensing objects in the urban environment. The stated findings consist of concrete ideas and/or approaches to cope with the named issues.

3. SMART TRANSPORTATION APPROACHES

Based on the mentioned transportation-related issues in Section 2, there are three major research fields the mentioned issues can be separated in: smart cars, smart traffic controlling, respectively sensor-based networks, and smart bikes. Hence, this section is separated into three subsections accordingly to get into detail and present each of the named issues and existing ideas and approaches to tackle these. In each of the following parts, one recently published paper will be presented in greater detail.

It should be stated here that the three named categories are not disjunct or strongly separated as solutions for cars, traffic controlling and bikes may interact or overlap with each other, i.e. regarding safety and infrastructure load balancing.

3.1 Smart Cars

In the area of motorized individual transport there are three challenges to take which stand in focus of current research and where solutions are required to get near to the future vision of smart transport respectively smart city. First, there is the well-known trend of an increasing amount of information technology in cars. This trend can be constantly observed in the past and there is no indication for this development to stop – rather the opposite is the case. With this in mind, the technological complexity of cars is growing as well. Hence, there is a demand for solutions to keep cars usable for its passengers and especially the driver.

One approach of getting the complexity off from driving a car is to fully automate the process of driving. This is a quite old desire of humans, but there currently is no convincing solution. Nevertheless, there are promising attempts in this field and one of those has been developed by researchers from Bangladesh. Nazmul Hasan et al. [13] published a complete idea for a solution to fully automate driving a car. A major difference of their approach is the fact that such a system can only be realized by involving the environment in which the car should later be able to drive. They do not only built a solution for an autonomous car but a combination of an intelligent car, a traffic system and the road environment. The researchers split their problem into subtasks: sensing the environment for obstacles, navigating the car to its destination, planning the actual motion process, which especially includes a safe and trustworthy ride, and the decision making of the car based on the three former aspects. The proposed solution is based on systems that already exist, such as Adaptive Cruise Control (ACC) that is today used to assist drivers by keeping a certain speed and distance to cars in front and autonomously break in dangerous situations, so the solution is not created from scratch which makes it even more promising. The authors mention as well the (not to underestimate) social challenge of accepting an autonomous car. The fact that it is built upon already well-known technology supports a fast acceptance and adaptation. Whereas the proposed solution dramatically helps to reduce the complexity of cars while driving by eliminating an actual driver, there is an enormous drawback regarding the realization effort. This completely results out of the fact that the driving environment, respectively the road, needs to be equipped with sensing technology. This is costly, limits the reachable area and can consequently become a problem when introducing such a system. Nevertheless, this approach is promising and finding a solution to overcome the vast effort could potentially lead to the introduction of such a autonomous driving system.

One popular company also works on the idea of autonomously driving cars: Google. As a matter of fact, projects initiated and funded by Google arise higher public interest so that a vast amount of press publications tackle that project and discuss various problems occurring in conjunction with the new invention. So did an article by Spinrad, published by Nature in the Science Fiction section [15]. He tackles a major legal problem of autonomously driving cars: In the usual case, a driver has to pass a test in advance to driving a car as a legitimization to do this. In case of autonomous cars the driver is the car itself or rather Google as the one who contributed the implemented logic and technology. Hence, Spinrad wrote about a fictional and exaggerated scenario of Google/Google's car taking the driving licensing test. Whilst the scientific character of the article is questionable, Spinrad points out major characteristics of autonomously driving cars. One major fact is that there is no way to interfere the driving process though a passenger as there is no steering wheel, no pedal and no speedometer. Car control mainly works via voice commands (first and formost because the major motivation of autonomous cars for Google is the mobility of physically disabled people who are unable to drive normal cars). Finally, the car has to pass the license test completely by itself. As the theoretical test is obviously no real problem, the practical part is of major interest. Spinrad concludes that the car obeys each and every driving rule exactly and has excellent parking capabilities which is good to pass the test, but in reality, it seems to be too strict. Furthermore, the test needs an update to allow autonomous cars as, for example, the look over the shoulder cannot be realized by such a car.

Reducing complexity can of course be less ambitious but less far away from its realization. There are very recent attempts of several car manufacturers like the Bayerische Motoren Werke AG or Tesla Motors, Inc. to establish first cars that make a complete switch from gasoline-based motors to fully-electronic vehicular drives. The switch from oil-based fuel like gasoline or diesel to electricity is much more radical than just exchanging the liquid that has to be filled into the tank. The technological background is completely different. The only effective commonality of both drive systems is the semantics of a car with four wheels with a passenger cabin plus luggage trunk and the ability to move to a destination of desire. This means a lot of things to change about what people know and expect from cars. One major point to consider is the maintenance effort. Whereas all-electric vehicles are supposed to have longer service intervals compared to usual fuel-based cars, recharging the battery lasts longer and is needed more often in average. Hence, there is a demand for systems that make the overall maintenance more convenient for the driver or owner. Therefore, Ferreira et al. [7] developed a smartphone app that makes it easier to get car-relevant information immediately and ubiquitously. The actual contribution goes beyond the development of an app as such a system requires the creation of an appropriate infrastructure behind it. This infrastructure mainly consists of a communication technology platform and a recommender system. A main issue the solution tackles is the named charging problem. Hence, the app shall serve the user charging-relevant information that fits to its personal usage behavior. This consists of charging recommendations, status information and predictions about the current reach of the car. Overall, the app's intent is to make using an all-electric car more convenient and practical. A major drawback for today is that the switch from usual fuel to electricity still leads to a loss in convenience when it comes to driving longer distances which cannot be compensated by an app as it just mitigates symptoms, but does not address the actual problem of the inability to charge a car to a state that allows a longer-distance ride.

A second major issue regarding cars that is tackled today by researchers is the need for an increased safety and security. Some mechanisms will be presented later on in relation to sensor-based networks which is more traffic-system-related than just car-related. But next to avoiding accidents by monitoring activities outside the car, safety and security can also be realized by monitoring what happens inside a car. Based on this approach, the two researchers Shaikh and Kate from India [14] propose a safety and security system based on the ARM[1] platform. The system mainly consists of a face detection system, a GPS[2] location tracking module, a GSM[3] module for communication purposes and a controller. The presented system is able to detect theft and can help to get back a car in case it is lost. Whereas today's usual car security systems consist of many sensors and cause complexity, weight and costs, the ARM-based solution is an attempt to simplify this system dramatically and offer more features at the same

[1] ARM = Advanced RISC Machine. RISC means a Reduced Instruction Set Computer.
[2] GPS = Global Positioning System
[3] GSM = Global System for Mobile Communication

time as it actively helps to get back the car in case it got lost. Additionally, it can ensure that only registered drivers are permitted to drive the car. To think a bit ahead, such a system can as well ensure that a driver is awake and able to drive which could directly lead to more safety.

Next to the problem of increasing technical complexity and increasing demand for safety (and security), there is the problem of an increasing demand for parking space in urban areas. There are usually two major attempts on coping with that problem: First is the approach of reducing the number of cars actually needing a parking lot in a city and second is the introduction of routing systems that can lead a car looking for a parking lot to a free one near the actual destination of travel. As the first attempt is an approach based on avoidance, the second one actually tries to make today's parking process more efficient. According to the smart car idea, the second approach is of more interest here. The first idea can be realized by making alternative ways of travel more attractive than going by car (e.g. by introducing high parking fares in inner city areas and establishing free or affordable Park+Ride spaces in the outer city area with attractive ways to continue the travel inwards the city).

One important aspect in tackling parking problems in urban environments is the determination of how much parking space should be available. Circella [5] deals with this question and emphasis the importance of finding the right level, because too less or too much parking space both have its downsides. Offering less space than needed will lead to increased traffic jam and environmental pollution in consequence. On the other hand, an overcapacity is supposed to lead to traffic jams as well as it supports the increasing attractiveness of individual transportation by car. Hence, finding the right balance here will result in an optimal traffic load situation which is good for the green environment, economy and traffic-related safety on the road. To determine the balanced level of parking space to offer, Circella introduces a model that allows a kind of simulation of different parking policies while respecting several influencing factors. With help of this model it shall be possible to optimize the traffic load level.

Once, the amount of required parking space is specified, it is necessary to think about the way, a car will find an optimal parking lot efficiently. Routing techniques already exist. They can be found as electronic street signs that show up the way to the next few parking facilities, ideally in conjunction with a display that shows whether there are free parking lots and how many. Next to those signs which only can be seen when driving in the destination city, there are various smartphone apps available that allow remote access to information like location and amount of free parking lots. That allows an early planning of the whole route. Many navigation solutions offered today include a way of finding parking space as well, but often do not offer real-time information. The systems mentioned allow finding parking areas, but are far from ideal. Parking is a dynamic and constantly changing process in a large city. The information accessible through signs, displays and apps are only an instantaneous snapshot of the current situation. The moment you arrive at the desired parking area might offer a different situation. Ideally, one specific reserved parking lot is waiting for the car and allows to drive straight to it. This would avoid unnecessary driving effort and uncertainties of parking facility availability.

Gopalan et al. [9] propose a concrete concept that allows a trustworthy system for parking lot reservation including mechanisms to monitor the parking area and to track the parking spot availability. The proposed solution is based on text messages as front-end for the user (as SMS[4] is very popular and accessible by most people) and uses OSGi[5] as a middleware that allows efficient communication between sensors and the system. The system manages the parking process by monitoring the available space, reserve space and managing incoming reservation requests.

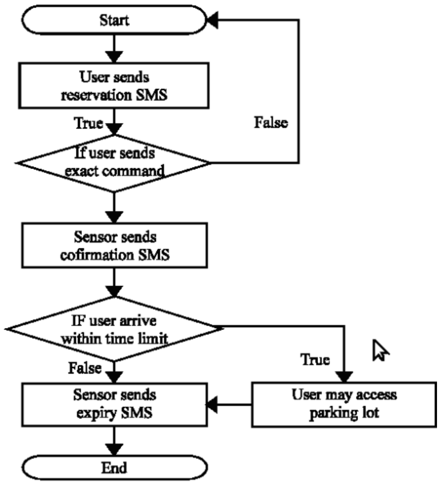

Figure 1: Process of reserving a parking lot [9]

Figure 1 illustrates the workflow to go through when a user wants to book a parking spot. There are the following steps:

1. At first, the user sends its reservation text message (via normal SMS) to the parking system.
2. Given the user sent the message correctly, the system will proceed. Otherwise he has to try again and the system goes back to the beginning.
3. The system will send back a confirmation via text message.
4. Now the user has the chance to use the reserved parking spot within a given limit of time. If he does not arrive within this limit, the reservation is no longer valid.

The parking slot reservation system is based on the OSGi framework *Knopflerfish* as the middleware that acts as a communication layer between the operating system plus the hardware and the solution-related software (the actual application, basic application facilities, such as user interface or SMS, and domain facilities, such as time and traffic management). The actual application is especially made up of the following four elements: Parking reservation, parking light detection, pathway detection and enhanced driver awareness.

[4]SMS = Short Message Service
[5]OSGi = Open Source Gate Initative

The realization of the system uses – next to Knopflerfish as OSGi communication framework – Eclipse as the IDE[6] for Java, MySQL to create and manage the database to process the reservations and ZigBee as communication technology for sensors which is IEEE[7] 802.15.4 compliant.

3.2 Smart Traffic Controlling – Sensor-Based Networks

The increasing load of urban traffic infrastructure leads to a new level of certain challenges. Safety plays a key role here, as well as dynamic traffic routing to balance load according to the current activity for an optimal traffic flow.

One major problem of urban traffic is the amount of accidents. Urban environments usually experience a high traffic load with lots of cars on the road. Confusing situations on the road, pedestrians, bikes and trams are challenging for each participant on the road. Here, it would help if there was a kind of "intelligence" in the infrastructure that supports each participant to get along with difficult situations. Indeed, there already is some kind of this intelligence, though it feels rather trivial: usual traffic control systems like traffic lights. They control the traffic flow and newer traffic light systems even recognize upcoming cars to realize a traffic flow without halts whenever possible. But the published findings of Karpinski et al. [10] suggest a system that goes even further by proposing a fully-scalable wireless network that consists of sensors which are able to monitor the surrounding traffic situation. The sensors are placed alongside the road. The gathered information can be used to identify potentially dangerous situations then and warn the affected road users. The publication focusses on the required software architecture and technical challenges that arise. The major challenge is the hardware-side realization, because of a high financial effort to setup the wireless network and to equip cars with the technology to react on warnings. On the other hand, Karpinski et al. suggest further applications for such a network setup as it can fulfill additional purposes:

- The network can track vehicles over longer distances to estimate travel-times.
- The system could count vehicles to observe the traffic load.
- Pedestrians can be recognized to beware of accidents there.
- The observation of driving patterns allows proactive warning in potentially dangerous situations.
- Next to the observation of road users, the network can monitor road conditions as well as offering a kind of broadcast service.

The approach of networked sensors is a promising one, but the high costs are a major argument for rejecting the realization at the moment. To avoid the high infrastructure costs, Barba et al. [2] suggest the realization over Vehicular Ad Hoc Networks (VANETs). The publication proposes a more lightweight networking solution that does not necessarily require the existence of a large network infrastructure. On the other hand, VANETs are as well able to handle and interact with infrastructure sensors as well, such as traffic lights.

A challenge that arises in conjunction with the introduction of sensor-based networks in urban areas is the combination with already existing conventional traffic monitoring and control systems. Kostakos et al. [11] investigated in this field with focus on the Finnish city Oulu. The network discussed here has the purpose of counting and tracking cars to observe the traffic volume on the city's streets. Therefore, sensors can be of different kind, e.g. magnetic inductive loops or cameras. They are connected wirelessly with a network and can send data into an (already existing) dedicated traffic control center. The center takes use of the new sensor network as described in the list above from Karpinski et al. [10].

Using cameras is mentioned in Kostakos et al. [11] which is an interesting approach, Calderoni et al. [3] investigated on too. They present *City Kernel*, a system that is able to "handle several subsystems, each addressing a specific sensor network" including a wide traffic control approach based on cameras. A key aspect of the findings is that cameras are relatively versatile sensors which allow the network to serve various purposes and can be installed in a cost-saving way by connecting them over the local power supply network with small embedded controllers that are able to send the data wired or wirelessly to a data center which then can process the data. It has to be said that the camera-based system does not serve the purpose of real-time recognition of dangerous situations like Karpinski et al. [10] suggest.

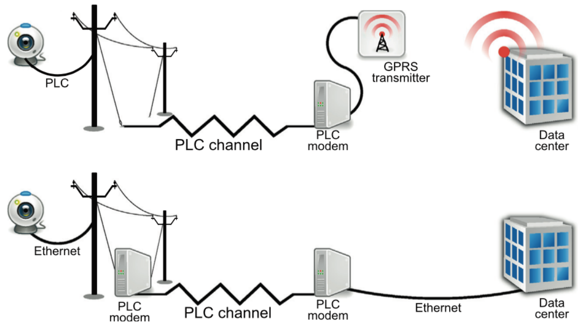

Figure 2: Top-level schematic architecture of the communication structure presented by Calderoni et al. [3]

The architecture proposed by Calderoni et al. [3] is mainly based on three basic concepts presented in Figure 2:

- The first part is the *WTC*[8] sensor network represented by optical sensors or cameras. This can be seen as the outer left part of Figure 2. This network is relatively versatile and effortless yet cost effective in its application, because it is able to count and classify cars, compute moving speeds and detect traffic characteristics.

[6]IDE = Integrated Development Environment
[7]IEEE = Institute of Electrical and Electronics Engineers
[8]WTC = Wise Traffic Controller

- The network has to be connected via PLC^9 using the existing power line infrastructure. This makes it cost effective to set up. In Figure 2 this is represented by the middle part.
- The right part of the shown figure describes the data collection and processing in a centralized data center. The last mile communication will be realized as usual via *wireless mobile or wired stationary Internet connections*. The interface between PLC and Internet connection will be realized via a PLC modem.

Probably the most feasible solution lies in between the given approaches. Perhaps, a VANET-based approach [2] in combination with a well-integrated camera-based network [3] is a good compromise to get out the most: a dynamic and fast traffic monitoring system and a system that serves higher safety on the road.

3.3 Smart Bikes – Bike Sharing

To tackle tomorrow's challenging growth in traffic volume, evolving cars or improving traffic monitoring and controlling alone is probably not sufficient. This leads to a demand for alternatives that are less stressful for the urban infrastructure and environment. Public transport is one approach to tackle this, but as individual transport offers more flexibility and is popular, bike sharing could be an interesting approach here. It offers a high degree of flexibility in urban areas and it is less stressful for the natural environment. But still: It is not easy to convince people to switch from car to bike or even bike sharing.

DeMaio and Gifford [6] worked on finding an answer to the question of how to get people to make the switch based on the United States. At first, it is necessary to make clear what the concrete advantages and disadvantages of bicycling in urban areas are. For shorter urban trips, bikes offer clear advantages:

- It is possible to reach destinations that are generally underserved.
- There is less infrastructure needed.
- The costs are relatively low.
- Traffic jams are not really a problem for bicyclers.
- Bikes are environmental friendly.
- Using bikes is healthy.

Nevertheless, there are some disadvantages that make bikes not appropriate for everyone:

- Weather highly influences bicycling and sometimes makes it uncomfortable.
- They can easily cause dangerous situations for other road users and pedestrians.
- Certain disabilities can disqualify people from using bikes.
- The topography can prevent bicycling.
- They require riding skills.
- Bikes are only ideal for short-distance trips.

The mentioned drawbacks are not in every case easy to overcome and sometimes prevent potential users to accept bike offers. Additionally, not every transportation purpose can be addressed, e.g. the transportation of a reasonable amount of luggage. It can generally stated that bike (sharing) offers are no fully-qualified substitution to any other way of being mobile in a city. Bikes and bike sharing rather are additional concepts of mobility to reduce the traffic volume of the alternatives.

The paper [6] especially focusses on bike sharing and smart bikes instead of using own bikes as it offers more flexibility in mobility with other ways of transportation in combination. There are two separate major bike sharing concepts: a *community-based* bike sharing approach and a *residential* approach. The community-based one allows the rental of a bike from one of many locations and return at any other location available, whereas the residential approach means that the starting and end location is the same. The first one is clearly favored as it offers more flexibility for the user. The term *smart bike* is generally used in conjunction with bike sharing as it is a way to combine bike sharing with intelligent electronic systems to prevent theft and abuse of the service on the one side and allow an easy way to use the service on the other side.

The success of bike sharing services highly relys on the actual customer demand. The attractiveness depends on several different aspects. The service has to be usable conveniently and is has to be an attractive addition to other transit choices such as busses, trams and trains. Additionally, however bicycling needs less infrastructure than other ways of travel, riding by bike needs a bicycling-friendly environment which allows safe and easy riding. Hence, one way to make people switch from car to bike would be to offer good biking facilities and offer highly flexible and usable as well as affordable bike sharing services with less usage barriers.

An interesting case study to mention regarding smart bike sharing comes from Castillo-Manzano and Sánchez-Braza [4]. The demand for such a service in Seville (Spain) regarding the university community was tremendous so that the offered service supply volume was too low. The researchers measured a very high 6.6 % share of all mechanized trips where made by riding a bike. The majority of the users are students of the university. Accordingly, the average age is at a low level of 24 years. The most important reason for using bikes has been determined as to be the cheap price, followed by the possibility to avoid traffic congestion.

A common problem of different bike sharing services is an imbalance in the distribution of bikes. This problem has been addressed by the German researchers Vogel et al. [17] from Braunschweig. They therefore proposed a data mining

[9] PLC = Power Line Communication

technique to track the user activity of bike sharing services to identify certain activity patterns. Those patterns shall allow a demand forecast to eliminate the bike supply imbalance. The activity tracking is based on the amount of bikes in use, the specific time of the measurement and the location where activity has been tracked. These data can be evaluated and visualized to examine load imbalances. The general aim is to allow a high level of availability for the bike service at any time which "is crucial for the acceptance of such systems" [17].

A similar problem is the question of where to setup bike sharing locations. Vogel et al. [17] rather focussed on the question of how many bikes should be available at the defined sharing locations. The location aspect has been taken into consideration by García-Palomares et al. [8] in Madrid, Spain. The position of bike sharing locations should be chosen by demand estimations which take population, activities and public transport stations into consideration. The publication proposes a method based on GIS[10] to calculate the demand distribution in an urban area. Generally said: The more bikes and free bike parking slots are available the better as it ensures an ideal mobility for everybody who wants to attend the bike sharing service. Unfortunately, resources are limited, hence, the available resources (bikes, bike parking slots) have to be distributed as ideal as possible respecting the actual demand. This is crucial for the success of bike sharing services and this success is important to lessen a city's traffic infrastructure load. The methodology presented by García-Palomares et al. [8] is based on the following four steps:

1. *Distribution of potential demand:* This first step tries to obtain a potential demand for stations based on population and employment related to the buildings of a city as well as the trips generated by each minor area in the city. The results of such an analysis can be visualized like shown in Figure 3.
2. *Location-allocation models:* Based on the demand visualization shown in Figure 3, the actual location of intended bike sharing stations will be defined based on the amount of stations that should be positioned. This process involves rather economic and political parameters too like the wish to cover the demand as exactly as possible or the wish to cover the city area as completely as possible.
3. *Station capacity:* To decide how many bikes and free slots have to be available later on, the actual capacity of each bike sharing location has to be determined based on the data gathered in the first step.
4. *Station characterization:* Next to the question of sharing locations is the question of the availability of bikes and free bike parking slots. Such a decision is based on the demand determined in the first step, e.g. when people go to work in the morning, a bike has to be available in the area near their home and a free slot has to be available near work. This can be done by characterizing each sharing point in one out of the following four categories:
   (a) *Generator:* A generator is a location with an attracted trip and total trip ratio of less than 40 %. This is mainly the case with stations in the surrounding areas of a city where people live. Those stations need to serve bikes in most of the slots in the morning and need to serve many free parking slots in the evening.
   (b) *Mixed:* The attracted trip and total trip ratio is between 40 and 60 % at mixed stations. The ratio of available bikes and free slots should be balanced during the whole day.
   (c) *Attractor:* If the attracted trip and total trip ratio is between 60 and 80 %, the station should be characterized as an attractor. Those stations are located in areas with mainly trip destinations like business areas where a lot of people work. This is the opposite of a generator station: in the morning, there should be mostly free parking slots and in the evening, mainly bikes have to be available.
   (d) *High attractor:* If the attracted trip and total trip ratio is over 80 %, nearly every available parking slot should be free in the morning at such a high attractor station.

[10] GIS = Geographic Information System

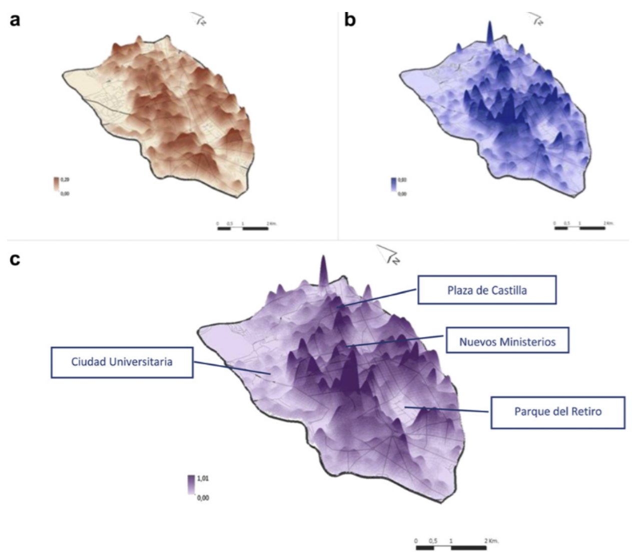

Figure 3: Example Madrid. Density of generated trips (a), attracted trips (b) and total trips or potential demand (c) in trips per qm. [8]

Based on the described methodology, the location of bike sharing points can be determined and a demand-related bike serving strategy can be created. Based on the categorization in the last step, a restocking mechanism can be established so that bikes can be collected and distributed nearly ideally according to the estimated demand. Finally and in consequence, a smart bike sharing service can be offered that is attractive as an alternative to usual inner-city mobility solutions like going by car or public transport systems. This potentially reduces the traffic infrastructure load, especially in rush hour times like in the morning and evening when a lot of people go to work or return home. But the establishment of a bike sharing service does not only include offering bikes and an easy user workflow, but also to offer a bike-friendly and safe traffic infrastructure.

4. CONCLUSIONS

This paper served as an overview of current research fields in the area of mobility in future urban environments. The umbrella term of the presented strategies is *smart transportation* in context of the smart city or even smart planet. Based on the challenges in the future derived and presented in Section 2, different approaches that came up in the latest research publications were presented in Section 3. All presented findings are interleaving. It is necessary to handle the growth in individual transportation by car in the future as especially urban environments have to deal with a lack of space and a (at least temporal) high infrastructure load. A large city has to cope with those new challenges. This leads to the necessity of advanced controlling and monitoring mechanisms, too. And traveling alternatives should be taken into consideration as well, like bike sharing services that could be seen as a flexible and easy to use supplement to existing transport systems to balance the traffic volume and be more environmental friendly.

But even if the presented concepts are very promising and some of them can be introduced soon, there is still a lot of work to do. This is especially not solely focussed on the technological part. A smart city does not only consist of a "smart environment", but "smart citizens" too. Previous habits will have to change to fit the environment in the future. To state an example, it may be necessary in the future to increase the general willingness to use a bike instead of a car – not only to save money, but to save energy, avoid emissions, improve overall health and avoid traffic congestion.

5. REFERENCES

[1] K. Al-Kodmany. Sentient city: Ubiquitous computing, architecture, and the future of urban space. *Journal of Urban Technology*, 19(3):137–140, July 2012.

[2] C. T. Barba, M. A. Mateos, P. R. Soto, A. M. Mezher, and M. A. Igartua. Smart city for VANETs using warning messages, traffic statistics and intelligent traffic lights. pages 902–907. IEEE, June 2012.

[3] L. Calderoni, D. Maio, and S. Rovis. Deploying a network of smart cameras for traffic monitoring on a "city kernel". *Expert Systems with Applications*, 41(2):502–507, Feb. 2014.

[4] J. I. Castillo-Manzano and A. Sánchez-Braza. Managing a smart bicycle system when demand outstrips supply: the case of the university community in seville. *Transportation*, 40(2):459–477, Feb. 2013.

[5] G. Circella. Envisioning parking strategies in the framework of sustainable urban transport. *TeMA : Journal of Land Use, Mobility and Environment*, 2(1), 2009.

[6] P. DeMaio and J. Gifford. Will smart bikes succeed as public transportation in the united states? *Journal of Public Transportation*, 7(2):1–15, 2004.

[7] J. C. Ferreira, V. Monteiro, and J. L. Afonso. Vehicle-to-anything application (v2anything app) for electric vehicles. *IEEE Transactions on Industrial Informatics*, 10(3):1927–1937, Aug. 2014.

[8] J. C. García-Palomares, J. Gutiérrez, and M. Latorre. Optimizing the location of stations in bike-sharing programs: A GIS approach. *Applied Geography*, 35(1-2):235–246, Nov. 2012.

[9] K. Gopalan, K. Sairam, R. Nandakrish, and V. Venkatesh. Competent smart car parking: An OSGi approach. *Journal of Artificial Intelligence*, 6(1):43–51, Jan. 2013.

[10] M. Karpinski, A. Senart, and V. Cahill. Sensor networks for smart roads. pages 306–310. IEEE, 2006.

[11] V. Kostakos, T. Ojala, and T. Juntunen. Traffic in the smart city: Exploring city-wide sensing for traffic control center augmentation. *IEEE Internet Computing*, 17(6):22–29, Nov. 2013.

[12] M. Krezdorn and C. Hofstatter. IV. zerstörung - der kampf um die seele einer stadt, Nov. 2014.

[13] M. Nazmul Hasan, S. M Didar-Al-Alam, and S. Rezwanul Huq. Intelligent car control for a smart car. *International Journal of Computer Applications*, 14(3):15–19, Jan. 2011.

[14] J. R. Shaikh and S. M. Kate. ARM7 based smart car security system. *International Journal of Engineering Trends and Technology*, 3(2), 2012.

[15] N. Spinrad. Google car takes the test. *Nature*, 514(7523):528–528, Oct. 2014.

[16] K. Su, J. Li, and H. Fu. Smart city and the applications. pages 1028–1031. IEEE, Sept. 2011.

[17] P. Vogel, T. Greiser, and D. C. Mattfeld. Understanding bike-sharing systems using data mining: Exploring activity patterns. *Procedia - Social and Behavioral Sciences*, 20:514–523, Jan. 2011.

[18] J. Zhao, W. Deng, and Y. Song. Ridership and effectiveness of bikesharing: The effects of urban features and system characteristics on daily use and turnover rate of public bikes in china. *Transport Policy*, 35:253–264, Sept. 2014.