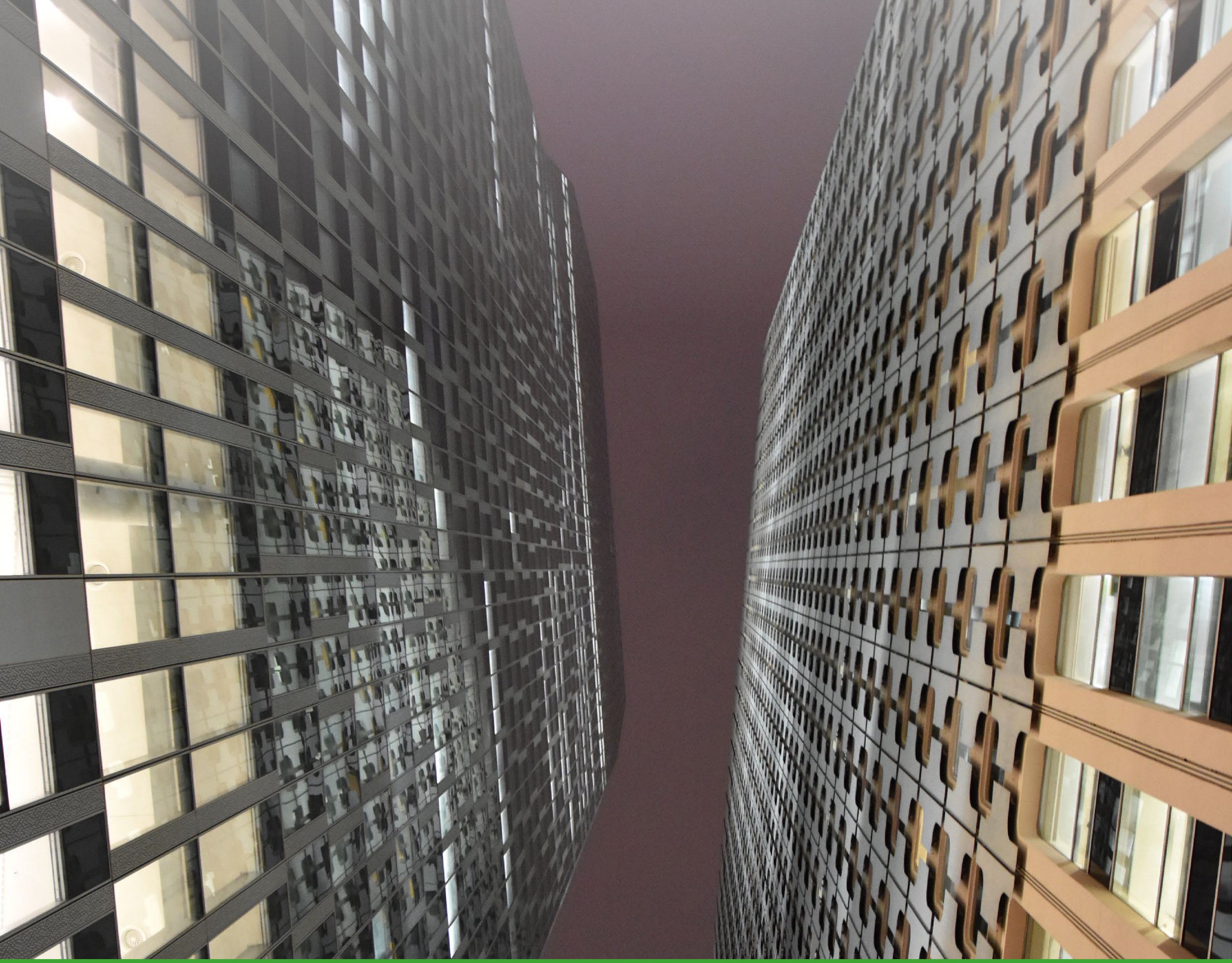

Regulatory Challenges for Smart Cities

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contents

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Regulatory challenges for smart cities

This issue of the Network Industries Quarterly looks into the regulatory challenges facing the development of smart cities. With the acceleration of technological developments in network industries and, in particular, in infrastructures, there is a constant need to review regulatory schema. Demographic changes, climate change, and the evolution of Information and Communication Technologies (ICTs) are disrupting the traditional landscape of urban infrastructure services and questions are arising. How should the sharing economy be regulated in order for regulators to invest in the infrastructure that supports it? How should public goods and services including transportation, telecommunications, water and energy be managed and distributed? While the possibilities are exciting and innovation continues to gain momentum at an accelerated pace, challenges are inevitable especially when it comes to infrastructure financing and the general management of smart cities.

Following the 6th Conference on the Regulation of Infrastructures which took place on 16 June 2017 with a particular focus on the regulatory challenges facing smart cities in the transport, telecoms, water and energy sectors, four papers were selected for this publication due to their topical relevance. **Olivera Cruz** and **Miranda Sarmento** address the regulation and financing of smart cities through Public Private Partnerships (PPPs), and how that financing can be put to use to make infrastructure smarter as quickly as possible through an in-depth analysis of the various PPP models used to date, and possible improvements. **Bock** and **Hosse** present a digital model in development for the planning, tracking and analysis of passively generated mobility data for regulators. The model aims to facilitate the use of intelligently managed renewables by providing easy alternatives for the car to transport users. **Marlot and Brunel** look at Mobility as a Service (MaaS) and how regulation can incentivise consumers to choose shared mobility over the private car. Finally, **Knieps** provides an overview of the network economics of smart, sustainable cities, with a focus on the potentials for sharing activities and prosumage, as well as smart congestion management.

dossier

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Public-Private Partnerships and Smart Cities

Carlos Oliveira Cruz*, Joaquim Miranda Sarmento**

Recent technological developments on urban infrastructure are reshaping the way we manage, finance and regulate public infrastructure. Existing Public Private Partnership (PPP) models need a significant restructuring, to be able to provide an adequate response to the smart infrastructure challenges.

Introduction

The world is changing and revolutionising the models by which we manage and operate urban infrastructure, whether it is transportation, water, energy or communications. Along with the digitalisation of infrastructure and the emergence of smart cities, there is a worldwide trend of increasing the involvement of the private sector in the financing and direct operation of urban infrastructure and public services (Rouhani et al., 2016; Iossa and Martimort, 2015; Roumboutsos, 2015). Large transportation investments such as metro systems, commuter rail or bus-rapid-transit are being developed with the active involvement of the private sector (Chen et al., 2016; Berechman et al., 2006; Fiorio et al., 2013). The same can be observed in water supply systems and waste management or energy production/distribution (Carpintero and Petersen, 2016; Kanakoudis and Tsitsifli2014).

Infrastructure needs to become smarter. This urgency is claimed by all main stakeholders: users, operators, regulators, and governments. Users today are much more demanding towards extracting real time information from the infrastructure, to help them decide and optimise their personal choices. This is particularly relevant in the transportation sector, where users want to know how long the journey will take with existing traffic conditions, what the alternative routes are, and how much the travel will cost. It is also relevant in the energy sector, where the potentially different applicable tariffs can steer consumption patterns towards more economically rational ones. The same applies to the water sector. For operators, the need for more information about infrastructure is due to several reasons: i) to understand existing usage of capacity and help them (when applicable) to more effectively plan the services; ii) to have more information on existing asset conditions, allowing for more effective maintenance activity planning, thus decreasing the overall life cycle costs and increasing the value of investments; iii) to develop target actions able to influence consumer/user behaviours towards more cost-effective ones. Regulators need more data to support their regulatory activity. Most of the regulation today is based on administrative reporting from operators and users, making the exercise of regulation a reactive process. To be able to have active regulation, capable of influencing and changing undesirable behaviours, regulators need to have access to more and better data, as well as more sophisticated big data analysis models. Last but not least, governments need to have more informed decisions. It is necessary to have more complete and reliable data towards existing patterns and asset conditions, to be able to have a more informed decision regarding planning of infrastructure investments and regulatory changes.

PPPs and smart cities

Traditional PPP approach

PPPs emerged as a panacea for solving infrastructure gaps. Based on the theoretical principle that private sector expertise can increase efficiency and reduce cost in public services, in reality, PPPs were most commonly used as a mechanism to leverage private financing to compensate a loss in public financing.

The model provides several benefits, but the reality shows that there is a significant value at risk, with potential losses, particularly taking into account the negative effects of ex-post renegotiations (for more on PPPs successes and failures, please see Cruz and Marques, 2012; Sarmento and Renneboog, 2016; Button, 2016).

The PPP model has been based on a relatively stable and known rationale. For a certain project, the private sector calculates the required CAPEX (capital expenditure) and OPEX (operational expenditure), which is facilitated by the existence, in most cases, of several existing similar sys-

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An extended version of this paper under the title “Reforming Traditional PPP Models to Cope with the Challenges of Smart Cities” was presented at the “6th Conference on the Regulation of Infrastructures. Regulatory challenges for smart cities” (best paper awarded) and has been accepted for publication by ¨Competition and Regulation in Network Industries”.

tems, and forecasts the revenue (or uses the forecasts provided by the government). Measuring the level of risk of the project (e.g. country, project and financial risk), the private sector decides on the expected return.

The design, structuring and assessment of a PPP is based on a forecast of costs and revenues plus a risk assessment to determine a risk-adjusted return on investment. This is often known as a "base case", which takes the form of an Excel file with all projected CAPEX, OPEX, revenues and/or any public subsidies. The benefits of involving the private sector are reducing the CAPEX and OPEX. Although the private cost of capital is normally higher than public borrowing, the efficiency in construction is expected to decrease the overall CAPEX. Based on these forecasts one can calculate the project's Net Present Value (NPV) and Internal Rate of Return (IRR), the two most commonly used decision parameters. But the application of PPP is now evolving from traditional infrastructure, with a low level of innovation, towards more innovative and technological infrastructure based solutions.

Types of PPPs in "smart cities"

To illustrate how PPPs are being used, or not, in different levels of technological innovation, we have created three classes for PPP development: "Business as usual" PPPs; "Incremental innovation" PPPs; and, "Ground-breaking innovation" PPPs.

- "Business as usual" PPPs refer to those typical BOT projects or concessions for the operation of the systems. They generally involve long term contracts, (20 years or more depending on the levels of investment), and involve significant private sector financing.
- "Incremental innovation" PPPs concern those PPPs developed for partial subsystems, such as ticketing systems, or the operation of electric fleets. These are technological upgrades to existing systems, but do not represent a restructuring of the backbone of the system nor do they provide a disruptive approach. Their purpose is to upgrade the service, maintaining existing business models and structure.
- "Ground-breaking innovation" PPPs are those disruptive improvements, building new business models and entirely restructuring existing mobility structure.

The classification "Business as usual" PPPs does not mean that there is not any type of innovation in those projects. One would expect that innovations regarding smart sensing of infrastructure (e.g. in tunnels, pavements or bridges) or signalling and management of metro and rail operations, is incorporated as they may represent a gain in efficiency. But the receipt is essentially prescriptive, meaning that the public sector determines, and specifies, the level of technological incorporation, the systems/subsystems used, and where innovation should be integrated (e.g. Hohoot Metro Line 1, Mongolia).

The emergence of what we designate "Incremental innovation" PPPs aims at establishing PPPs for specific sets of subsystems, for example, ticketing systems, vehicles, communication and control (e.g. Athens Bus Ticketing System or Electric Bus System in Bangalore). The use of PPPs has been more linked to heavy infrastructure development, such as roads, water systems, airports, dams, etc. Over the last decade, there has been a growing trend towards increasing the use of PPPs in "soft systems", such as ICT systems. Some of these systems are intrinsically connected with the operation of heavy infrastructure, but, whenever possible, the trend has been to vertically unbundle. An example of this unbundling is separating signalling and communication from construction and management of rail infrastructure or separating ticketing systems from the operation and management of buses or metro systems (e.g. Athens in Greece or Belgrade in Serbia).

Cases of "Ground-breaking innovation PPPs" are scarce and more linked to isolated exploratory pilot actions that, if successfully tested, can later become a "business model". It resumes to the possibility of testing "proof of concepts".

To accelerate the development of "smart" "Business as usual" PPPs, the model must evolve toward a quality of service model. Which will raise a set of other different issues, such as how to evaluate proposals and compare different bids.

Innovative PPP concepts

As mentioned, "Ground-breaking innovation PPPs" are still very scarce and linked essentially to pilot cases. The pilot cases, by definition, are developed within a controlled environment with several protections provided by public authorities and regulatory authorities, that, if successfully tested, do not necessarily mean optimal performance in the real business environment, nor that they are "bankable". Bankable "Ground-breaking innovation PPPs" are able to attach private equity and commercial loans, compatible with the level of risk of the project.

There are still few examples of PPPs developed in autonomous vehicles, big data analytics or any other type of disruptive technologies, to perform a truly comparative analysis of new vs. standard PPP models. In fact, these innovative PPP models are still at a conceptual and rather uncertain level. In fact, a current challenge for researchers is to provide guidelines for what can be future PPP models.

The new PPP approach will have to deal with significant risks particularly regarding planning, production, demand, financing and legal & regulatory issues. The structure of the risk-sharing agreement has always been a critical question for PPP development, and critics have highlighted the uneven and inefficient risk allocation of PPP projects. In a smart cities context, this challenge will increase, because the risks are higher. To avoid inefficient risk pricing, governments should avoid a full risk transfer approach, and retain some risks, such as legal and regulatory, on the public side. Financial risk can be mitigated by separating financing from PPP operation. The financing can be awarded through an independent competitive tender, avoiding any risk contamination from a riskier operation. This could have a potentially positive effect on the cost of capital.

To establish a true partnership, and share potential benefits, the public sector could have an equity stake in these new innovative PPP projects, as also suggested by the HM Treasury (2012) regarding the UK second PFI wave.

Conclusions

The medium- and long- term vision for the infrastructure sector, and ultimately for cities, will bring a radical change in the way we have been building and managing existing infrastructure assets. Although the overall levels of efficiency in water, transportation, energy and other infrastructure-based sectors has historically been improving, it has not been possible to have a highly cost-effective system. Costs remain high, and there is a strong political temptation to cut infrastructure spending, particularly when economic growth is low and public finances have strong constraints. The results are deteriorating infrastructure and lower quality of service.

One of the main drivers to decrease operating costs in the infrastructure sector (and raise capital for financing infrastructure development plans) has been to involve the private sector, but the potential for savings will not be much higher. Only a technological shift both in the management of the infrastructure itself (through smart monitoring), lowering life cycle costs, and on the demand side guiding and influencing smarter usage patterns, can provide a potentially large impact on efficiency levels.

But the risks of this new perspective are considerable. Traditional PPPs have been founded on the concept that the transfer of risk to the private sector improves the value of money of infrastructure spending. But the risks have to be "manageable", meaning, there has to be a certain degree of predictability so that the private sector can assess and calculate risks (and risk premiums). Most ground-breaking innovations in the infrastructure sector are not predictable. Applying traditional PPPs will mean that most projects will not be bankable given their extremely high level of risk.

A new flexible and truly shared partnership will be required to be able to attract the private sector towards smart infrastructure investments. It is unlikely that the typical contract-based concession will be adequate, because the level of contractual incompleteness will only increase when dealing with technological ground-breaking innovations. Mixed companies or project-specific third entities will most likely be adopted to allow a better incorporation of uncertainty.

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Planning Transport and Energy Infrastructure with Modelling on Demand

Benno Bock*, Daniel Hosse**

The authors are developing a scalable assessment of innovative mobility solutions such as shared mobility, electric mobility and autonomous driving. The system includes passively generated mobility data, an agent-based modelling software and an interactive website for the adjustment of parameters as well as the visualisation of results – '*transport modelling on demand*'.

Context and Aim

The energy transition from fossil fuels to intelligently managed renewables has a German name: '*die Energiewende*'. The term has been adopted by the mobility and transport sector using the similarly coined word '*die Verkehrswende*' – best translated to '*the mobility transition*'. It relates to a supposedly changing mobility behaviour as well as a more obvious evolution of innovative transport services. After decades of car dominance in planning and for the individual perception of being mobile, alternatives to the privately owned motorised vehicle are becoming more diverse. Services such as ride hailing or car-, bike- and scooter-sharing complement traditional options like bicycles, cabs, busses, trains, or simply walking. Electric and hydrogen propulsion additionally change the external effects of motorised transport. Furthermore, new services with autonomous vehicles are currently in a pilot stage. In short: the transport and mobility sector, which has been quite stable in the past, is now becoming increasingly dynamic (Lennert, 2017).

This dynamic development creates a demand for more flexible, cheaper and quicker planning procedures to assess and relate possible developments. Business intelligence tools from providers of large datasets of movement or tracking data try to address this demand. An alternative approach is to focus on the scalability of state of the art transport modelling combined with the increased data availability and the benefits of web-based data visualisation. The development and deployment of such a tool are part of the current research project '*ENavi*' funded as part of the '*Copernicus Projects*' by the German Federal Ministry of Education and Research. The authors are currently developing and testing a planning tool for the project addressing the efficiency of innovative mobility services and mobility measures.

Benefitting from Digitalisation

The concept for this planning tool includes passively generated mobility data, an agent-based transport modelling software (MATSim) as a base for an innovative automated modelling technology ('*transport modelling on demand*') and an interactive website for the adjustment of planning parameters as well as the visualisation of the modelling results. Past and current research projects like '*Berlin elektroMobil*' (Bock, 2012), '*e-GAP intermodal*' (Wappelhorst, 2014) and '*3connect*' have shown that agent-based modelling can be used to derive key performance indicators of innovative mobility services. On the other hand, the use of interactive web-applications as dashboards are increasingly popular for the mobility and energy sector and enable non-experts to explore and understand large datasets and hence also the output of transport models.

The described development also benefits from an increasing availability of mobility and energy data in form of open data or as proprietary data accessible through standardised Application Programming Interfaces (APIs) (Canzler, 2016). The simulations are based on various input data. All input data is standardised and its usage is scalable over the area of coverage. Most important are:

- Trip-data from the largest German travel survey MiD
- >400k trips gained by a local smartphone-tracking survey (Leppler, 2015)
- Commuter statistics from the Federal Employment Agency
- Governmental data on population numbers
- Data on infrastructure and land-use from OpenStreetMap
- Traffic counts using open data portals

The authors also include web-mining to acquire a robust set of data about free-floating and station-based shared mobility services. Shared cars, bikes and scooters, their stations and operating areas as well as their movements have been tracked since 2011 resulting in records of over 100 million movements (Kortum, 2016). Finally, this data is automatically integrated in the models to deliver estimates on demand as well as supply.

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The technique of agent-based modelling has been chosen for the analysis because of its ability and flexibility to analyse detailed service variations in space, price but also further product characteristics of innovative mobility services (Ciari, 2014). Multi-agent simulation also enables an estimation of people's activities which is planned to be used for estimates on local private energy consumption. The model has been created by using the open-source framework MATSim (Multi-Agent Transport Simulation) for agent-based transport simulation (Horni, 2016).

The entire process is aimed for models on local districts, German '*Landkreise*' and '*kreisfreie Städte*'. These areas can range from rural landscapes to metropolises like Berlin. A first step was the automatic integration of population estimates based on web-mined population data published by governmental bodies. The information is sub-annually integrated and post-processed to derive disaggregated population groups for smaller administrative areas. In a next step, a module was programmed to automatically create a modelled network for the same administrative units. The street network has been implemented in two levels: within a bounding box of the local district, a network with a fine structure including roads and streets of only local importance. For surrounding districts as well as parts of neighbouring countries, the network includes main roads and motorways to realistically include long-distance commuter trips.

The demand was created for two agent groups in a distinct way. For agents representing the local population, activities and trips start and end within the district. For agents representing commuters, either the start or the end may lie outside of the observed area. To simulate the traffic within the district, the first group was given detailed daily activity plans on the basis of data gained for similar regional types through surveys and smartphone-tracking. The second group of agents were allocated to origins and destinations of their commuting trips but no further attributes to their travel behaviour was given. Both steps have been automated for selected districts.

Usability and Data-Literacy

Besides the development of a scalable modelling tool, the second aim of the development within the ENavi Project is to enable a broader set of user groups to access mobility data and furthermore even create mobility scenarios of their own. The work on the UX-concept and interface design focuses on stakeholders with little or no experience in data-analytics and GIS tools. Representing the user groups, the identified personas used for the UX-concept are working within a communal or ministerial context, in the management of transport operators or as urban and transport planners. It is assumed that these user groups are the ones most likely to face the initially mentioned challenges.

Primary needs for information are the following:

- How high is the demand for a new mobility product in a currently unserved area?
- What are realistic volumes of traffic under which circumstances?
- Where do I get origin-destination data for specific areas?
- What are the consequences for the existing and planned network infrastructure?
- Which areas might benefit, which areas could fall back?

Conceptually, the website is divided into the three main sections 'Scenario Explorer', 'Scenario Creator', and an overview for specific use cases. Each section differs regarding the depth of provided information and the extent of

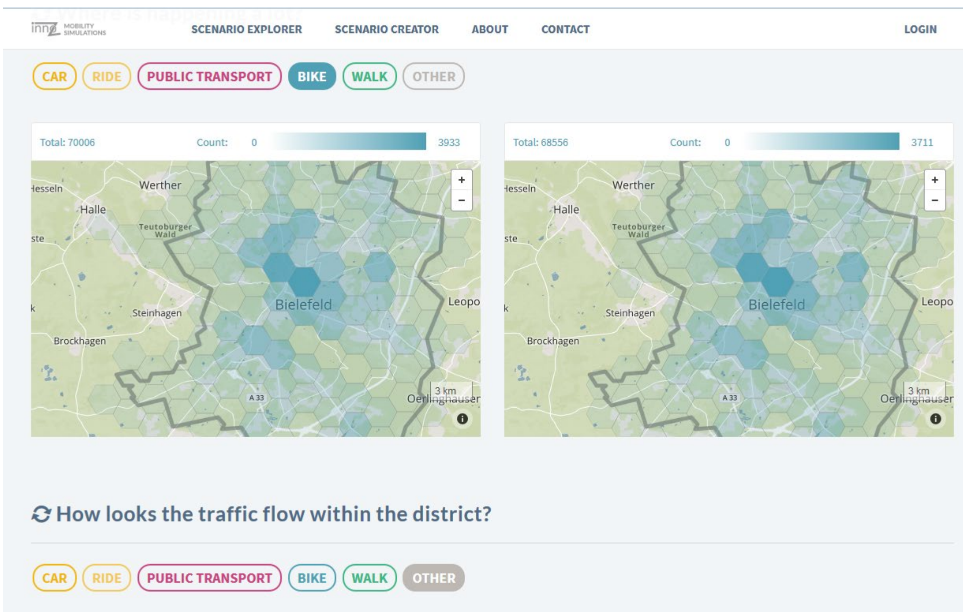

Fig. 1: Results for the distribution of bike rides in the Bielefeld District as seen in the current 'Scenario Explorer' of the website. Left is the base model for 2017.

functionalities to address the different experience levels of the users. This is most obvious for the 'Scenario Explorer', in which the user can view existing models of 2017 and 2030 for each district and in a further step compare this basic data with any own scenarios generated with the 'Scenario Creator'. The page of the 'Scenario Explorer' is designed as a storyboard so that the inexperienced user receives a better understanding of the full extent of accessible data by simply scrolling down the website (compare fig. 1). Elements are interactive so that further information can be derived be selecting items or clicking on buttons for further information.

Selecting the district and the scenario year and adjusting various parameters regarding innovative mobility services are the first steps to generating a new model (compare fig. 2). After confirming the model parameters, an automated process is started by clicking the create button. This process includes the extraction of data, the model generation within a network and a population generator as well as a demand estimate, the model simulation, the automated calibration method to represent modal split figures and traffic volumes and finally some basic analytics to visualise the results.

It is currently planned to include the following parameters:

- Electric mobility: fleet diffusion in percentage and density of charging facilities per population.
- Shared mobility: absolute figure of free-floating car- and bike-sharing vehicles as well as number of pods for station-based concepts.
- Autonomous vehicles: selection of public transport lines to replace with autonomous shuttles, fleet sizes of last-mile services around selected stations and of on-demand services (so called 'robot taxis').

Blanket Coverage of Mobility Data

Blanket coverage of modelled mobility data could be gained for most of the country. The authors could generate base models with the current main transport modes for approximately four fifths of the German districts using the automated procedure. Apart from 86 districts with a population above 320k inhabitants, which are still being processed, nine districts had issues with data constancies and terminated without result. For the other districts, initial results are promising, as distributions seem to be realistic after a first visual validation process. The topology of specific areas with similar survey data filters seems to have little effect on modal split figures. Consequently, cities with a strong deviation from the average of similar region types seem to be affected by significant deltas regarding figures of existing traffic surveys. A systematic validation is planned for a later stage of the development. Further potential for improvement is suspected in estimations for the fringe areas of the district and better data sources for the calibration procedure. Such data are traffic counts as diurnal curves and updated modal split figures for specific areas.

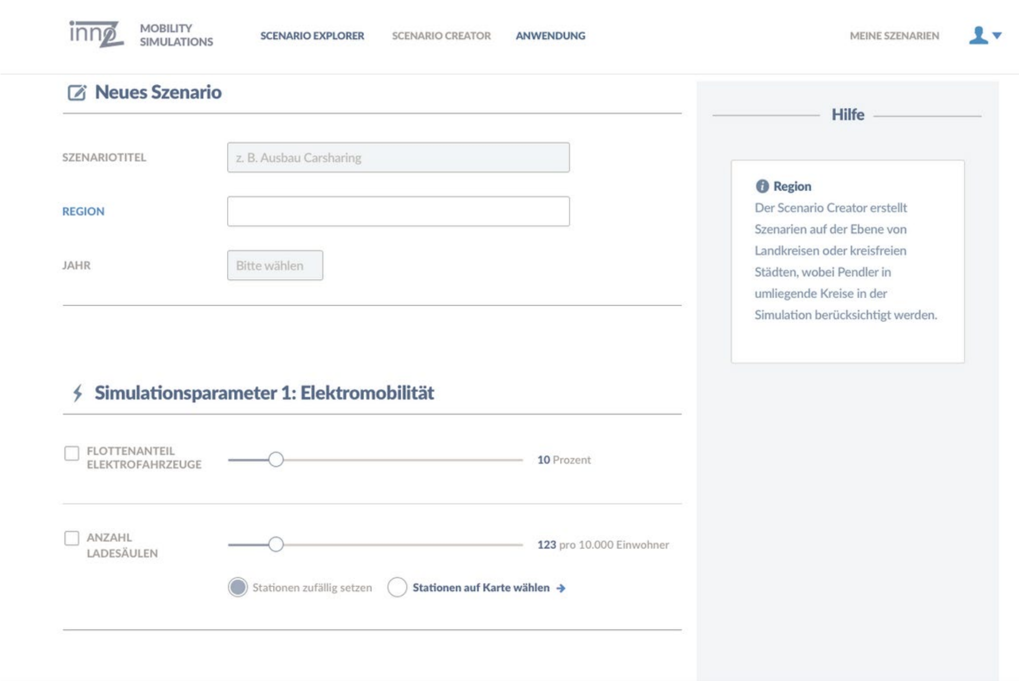

Fig. 2: Preliminary concept for an interface showing the potential parameters to create individualised future mobility scenarios

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Why Smart Cities need Smart Road Traffic Mitigation Policies

Grégoire Marlot*, Julien Brunel**

The digitalisation of mobility, and especially the autonomous car, will offer a unique opportunity to improve the transport system. Nevertheless, it will only be possible if most people use shared vehicles (cars, subways, trains, …). Strong regulations will be needed to achieve such a transformation.

* An extended version of this paper under the title "Why smart cities need smart road traffic mitigation policies" has been submitted for publication to "Competition and Regulation in Network Industries" and it is currently under review.

Introduction

Over the last 20 years, information technologies changed the economy and the way we live. More recently, they began to change the way we move: smartphones and platforms fostered the development of car sharing, carpooling, and optimized cab services. Nevertheless, the most drastic transformations are yet to come. The autonomous vehicle will allow combining shared cars and public transport to offer door-to-door personalized services, with the same freedom as a private car, at a lower cost for the traveller and for the community.

As a whole, the digitisation of mobility is perhaps the one and only opportunity to drastically improve the transport system without reducing mobility, increasing inequalities, or spending billions of public money in infrastructure and services. There is a condition: travellers and commuters must give up the private use of the car. Nevertheless, switching to shared autonomous cars will not be spontaneous for most car users.

The aim of this paper is to show the need for regulation in order to achieve "smart mobility". The first section emphasises the potential benefits of digitisation in the field of urban mobility. The second section shows why strong incentives are needed in order to switch to shared mobility. The last section discusses the opportunities for the implementation of "smart incentives".

1. The digitisation of mobility will allow for a drastic improvement of transport systems

a) Cheaper mobility, lower social costs

Autonomous vehicles will drastically lower the operating costs of cabs, buses, coaches, and lorries.

Today's cars spend most of the time parked[1]. Autonomous cars could be offered as a service by car manufacturers or third parties. These fleets of autonomous vehicles could be on the road most of the time. The capital cost of the car could thus be spread over a far greater mileage, decreasing the cost of the car per kilometre. Moreover, autonomous cars will make sharing easier, for long distance trips as well as for short distance urban trips. With the help of optimisation algorithms, sharing a vehicle could have little or no effect on the quality of service (waiting time, journey time, delays…), whereas the cost of the trip could again be cut by 2 or 3 (see for example Spieser et al. 2014). Finally, autonomous vehicles could foster the development of mobility, especially in rural and suburban areas, with better public transport services (better frequencies, new services…), at a much lower cost for the public authorities and the users[2].

Congestion, air pollution and safety are the most important social costs of today's road traffic in industrialized countries (see part 2). At this stage of the technology it is difficult to assess the effect of autonomous vehicles on congestion, pollution and safety. The most important point here is that the impact of the switch to shared cars on a large scale, alone or in combination with public transport, is probably greater in terms of congestion, pollution, energy efficiency, and safety, than the switch to autonomous electric vehicles in itself.

b) Shared mobility is smart: the end of the private car

Maximising the benefits of autonomous electric vehicles supposes giving up private cars, as much as possible, at least in urban areas. It is possible to design a very efficient urban transport system based on shared autonomous vehicles of various sizes (Canzler & Knie 2016) but, in such a system, the role of private cars, or cars used by only one person at a time, is very small (whereas it could be justified in rural areas).

Relying on light and heavy rail for massive flows of mobility could allow for a much smaller fleet of road vehicles, and a more efficient transport system, with faster travel

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[1] In the Paris area, only 63% of the cars are used on a daily basis, and for these cars the average time of use is only 1h30.
[2] The share of wages in the operating costs of public transport in France is more than 50%, excluding the Paris area.

within big cities, less congestion and less energy consumption (ITF, 2015). Walking, biking, and other personal transportation devices are also complementary to autonomous vehicles. All these transportation modes could be combined in door-to-door personalised services, with integrated ticketing and online payment, offering the same freedom as a private car, at a lower cost for the traveller and for the community.

As a whole, autonomous road vehicles could reduce drastically the cost of mobility if used where they are relevant and in the most relevant way (shared cars and public transport). This could mean more mobility, but also more purchasing power for households, less public spending on transport, and lower taxes: the "revolution" of the autonomous vehicle could not only mean a better and more efficient transport system, it could also mean a stronger economy.

2. Switching toward shared mobility will require strong incentives

Giving up the private use of cars would be a major shift in travellers' and commuters' behaviours. The preference for private cars has widely shaped our cities and transport policies. Most motorized travel is by car, despite huge investments in public transport. Drivers are incentivised to use their cars: even in the countries where fuel taxes are quite high, road users do not pay for their social costs. Calculations suggest that the average marginal social cost of an automobile in France is approximately two times the taxes and tolls paid by the drivers (see table below). In central Paris the marginal social cost of a car is nine times the taxes and tolls.

Marginal social costs, taxes and tolls for short distance road trips in France On the other hand, public transport is highly subsidised. In urban areas, public transport users are usually only paying for a fourth to a half of the costs of the service (the average figure in France is 35%).

The main explanation for such sub-optimal urban transport policies lies in the fact that road has always faced a strong political opposition. Most of the time the optimal tax is greater than the perceived cost of congestion and other externalities, and only the wealthier drivers could benefit from such a scheme. This is why there are so few examples of congestion pricing.

3. Smart incentives for smart mobility

a) New opportunities and new issues for transport policies

Within the context of sub-optimal urban transport policies, the digitisation of mobility may increase the competitiveness of cars (which means more demand for car mobility, more congestion, more urban sprawl, more energy consumption), while compromising infrastructure funding (electric autonomous vehicles will not pay fuel tax, whereas fuel tax revenues are, tolled roads excluded, the only way to finance road investment and maintenance – see for example Finger et al. 2017).

Nevertheless, the digitisation of mobility is also shifting the boundaries of what is possible for transport policies. Public authorities could be able to offer new public transport services, and to implement better regulations, at a lower cost. "Mobility as a service" (MaaS) could significantly reduce the cost of implementing efficient taxes and economic incentives. The pricing of mobility services could be efficient per se: the companies offering the services will probably try to maximize their revenues, introducing as much price discrimination as they could, taking into account not only the nature of service (shared or not) but also the day, time of day, and length of trip, with the customer/commuter being able to assess in real time the performance and cost of all the different offers. It already exists with services like Uber.

Marginal social costs, taxes and tolls for short distance road trips in France
(CGDD, 2017)

	Low density areas		Urban areas (excl. Paris)		Paris urban area	
c€/pas-km	Fuel car	Gasoline car	Fuel car	Gasoline car	Fuel car	Gasoline car
Marginal social cost	**8,38**	**8,89**	**21,87**	**23,98**	**24,00**	**28,71**
External marginal cost	7,78	8,29	21,27	23,38	23,40	28,11
Road traffic safety	2,00		3,30		2,40	
Climate change	0,60	0,57	0,60	0,57	0,6	0,57
Air Pollution	0,27	0,81	0,67	2,81	1,38	6,12
Noise	0,03		0,10		0,12	
Congestion	4,88		16,6		18,90	
Marginal cost of infrastructure	0,60					
Taxes and road tolls	**5,30**	**4,10**	**4,20**	**3,00**	**4,20**	**3,00**
Balance (MSC-taxes&tolls)	**-3,08**	**-4,79**	**-17,67**	**-20,98**	**-18,80**	**-25,71**

b) More efficient infrastructure funding

New taxes must be created in order to finance the infrastructure costs. These taxes could be paid by the households, or companies (which are already financing public transport in several countries, and especially in France), but it would not be efficient: these taxes would have an opportunity cost, whereas car users will not be optimally incentivised. On the contrary, because autonomous cars could be offered as mobility services, with a "pay as you go" charging system, it is possible to implement more efficient tools to finance infrastructures. The cost of infrastructure could simply be recovered by a tax on the price of the service .

c) Economic incentives beyond infrastructure funding

Funding infrastructures is only part of the problem: in France, current fuel tax revenues cover more than the full cost of the infrastructures, but road users do not pay for their social costs.

An important result of the economic analysis of congestion (see Small & Verhoef 2007 for a literature review) is that a road charge representing the marginal cost of the infrastructure and the marginal social cost of congestion, under certain restrictive conditions, will raise enough revenue to cover the full cost of the infrastructure. This self-financing property of marginal cost pricing is not true in rural areas, but it is in urban areas. In very congested areas, the marginal social cost pricing could even generate profits, allowing for subsidies in favour of public transport.

The congestion charge would be differentiated following the period, the hour, the specific areas of the city, etc., allowing for the funding of the infrastructure while giving the right price signal to road users. Nevertheless, even a road pricing scheme integrated in the pricing of the car services could raise some acceptability issues. Congestion pricing always means that more wealthy people are able to use a car whenever they want, whereas the poor cannot. Public authorities could thus choose to stay away from sophisticated pricing schemes, and just implement a flat tax to finance the infrastructure. In this context, it would still be possible to incentivise road users efficiently, by means of a tradable permit scheme (see for example Raux and Marlot, 2005). Such a scheme could use the same technology as the road pricing scheme, keeping the cost of implementation low.

d) A new role for public authorities

The digitisation of mobility challenges the role of public authorities:

- the regulation of transport in the city will be decentralised; currently, the regulation of cars is implemented by fuel taxes that are mostly collected on a national basis; with electric vehicles, new taxes must be created, and because the most obvious scope of the levy is the price of the service, theses taxes will be collected on a local basis;
- the nature and the objective of public authorities will change; tomorrow's urban transport policies will probably be less about subsidising public transport, more about implementing the right tax/pricing/tradeable permits scheme, encouraging shared mobility rather than private mobility;
- regulating car services does not mean that local public authorities should have the monopoly on them; nevertheless, as private operators will not implement an optimal solution for the welfare if they are not obliged to do so, public authorities should at least be able to implement, within the pricing scheme of these services, their own road pricing scheme (or their own combination of tax and tradable permits);
- another very important issue is to determine who will be the integrator of mobility services; here again, the frontier between private and public sectors is not obvious; public authorities could be the integrator of all transport services, but this is not necessary; they could keep the control of public transport services, impose a tax on the car services, and still all these services could be integrated and offered as a bundle by a third party.

What is strategic for public authorities is to keep the ability to implement smart incentives. Having the monopoly of the services is one way to do this, but not the only one. Another way is to have only the monopoly of the integration of mobility services. The only thing necessary is access to the data of all the transport operators, and obviously, the right to implement taxes or charges on car services.

4. Conclusion

Maximising the benefits from the digitisation of transport will require two things:

- to organise a transition as quickly as possible between a fleet of private, human-driven, fuel powered vehicles to a smaller fleet of pooled, autonomous electric vehicles (because most of the autonomous vehicle benefits disappear if the fleet is heterogeneous);
- to implement a "shared mobility" policy, incentivising commuters to use shared vehicles, whether they are cars, vans, buses, subways or trains.

The emergence of autonomous cars within the context of MaaS will make the switch to shared mobility easier. Nevertheless, it seems unlikely that these innovations alone will foster the development of shared mobility. There will be no smart transport without strong regulations. The public authorities will have to implement the right incentives: keeping the ability to do so will be strategic, in a world where the boundaries between private and public transport will be blurred, with new services competing with subsidised public transport.

Public authorities would probably be better off starting to implement the right incentives early: for example, they could implement driving restrictions (during the day or during peak hours) for drivers that are alone in their cars, such as the High Occupancy Vehicles lanes in many countries. They could also implement driving restrictions for the most polluting vehicles.

There are many other examples of existing measures that can be adapted or redesigned to foster the transition toward a smart urban transport system. What is very important is that public authorities should start implementing measures against the use of cars by lone drivers within the metropolitan areas as soon as possible.

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Network Economics of Smart Sustainable Cities

Günter Knieps*

The concept of smart sustainable cities gains increasing attention, upgrading the traditional public utility services with the potentials of ICT, in particular, IP based sensor networks, satellite based geopositioning systems and active traffic management within the All-IP Internet. Potentials for sharing activities and prosumage as well as smart congestion management strongly increase.

Introduction: ICT as driver for smart sustainable cities

The transition from dumb to smart networks is driven by rapid innovations in Information and Communication Technologies (ICT). Network capacity allocation decisions are increasingly made on a real time basis and less strongly day-ahead based as they were in traditional electricity or transportation networks. Thus adaptive production and consumption decisions are based on real time scarcity signals provided via smart meters, actuators and sensors. Moreover, the geo-locational dimension is taken into account. Important innovations in communication and sensor networks promise large potentials for smart networks driven by machine-to-machine communications called the Internet of Things (IoT) (OECD, 2012). On one hand, sharing activities and prosumage such as shared mobility or microgrids become more and more relevant. On the other hand, the increasing scarcity and congestion problems within urban networks can be approached with ICT based implementation strategies. The focus of smart sustainable city initiatives is on utilizing ICT for upgrading the urban infrastructure and services to enable adaptive real time behaviour based on data-driven feedback loops (ITU-T, 2015a; OECD, 2013: 8 f.).

From a network economic point of view, the complementary role of ICT based virtual networks for the design of smart physical networks is important. Physical infrastructures and network services within cities include local traffic infrastructure services, networked vehicles, renewable energy generation, storage and remote control of electricity consumption, intermodal local transportation by bus, train and cars, water supply and waste water management. Virtual networks are based on smart bi-directional metering, sensors, actuators and remote control by interactive machine-to-machine communication connected to broadband communication networks.

The architecture of IP virtual networks

The ICT based challenge to traditional network industries encompasses intelligent transportation systems, smart grids, sharing mobility, or more generally the App economy. Basic characteristics are: real time, adaptive decision making, location awareness, the interconnection of meshed sensor networks, and cities as hubs for big data (OECD, 2015, chapter 9). Although different physical network infrastructures and services vary strongly, depending on whether they are based on road, rail, water, airport or electricity networks, the complementary virtual networks are all based on the same ICT logistics of the Internet Protocol IP. Implementations of virtual networks consist of IP sensor networks with digital meters connected to data packet transmission within mobile and fixed broadband networks. Different physical network services have heterogeneous requirements with regard to complementary virtual networks. The innovation potentials of different virtual networks enable the scope of smart sustainable city services.

IP based sensor networks

Virtual networks are not to be considered isolated entities, existing separately for each smart city, but rather as interconnected with the All-IP Internet. Virtual networks may interconnect with other virtual networks or communicate with others outside the virtual network context, e.g. within a microgrid the aggregator must communicate the import/export decisions to the wholesale distribution network operator, the networked vehicle service requires communication with the cloud for general traffic status information, or home networks use multi-purpose broadband communications for electricity applications based sensors as well as for other ICT requirements (e.g. IPTV). Service continuity (e.g. networked vehicle services) may require multiple interconnected virtual networks (ITU-T, 2014, Knieps, 2016).

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The role of geopositioning

European Global Navigation Satellite (EGNOS) systems are improving accuracy and reliability by correcting the measurements in the GPS or Galileo navigation systems. Galileo enhancement for the smart cities is based on the accurate positioning of mobile vehicles. EGNOS combined with digital cellular technologies enables a large variety of real time and location tailored applications within smart cities. Various EGNOS based applications within smart cities are evolving, such as networked/autonomous driving, and safety-critical applications (ITU-T, 2015a: 83 ff.). From the network economic point of view, geopositioning systems are different from broadband network capacities because the receiving of positioning data is a public good where scarcity and congestion pricing are not relevant.

Active traffic management within the All-IP Internet

Virtual networks pose new challenges, not only for data generation (via sensors) and data processing (via cloud computing) but also for data transmission. The provision of the necessary All-IP bandwidth capacities is based on the seamless availability of heterogeneous IP-based broadband infrastructures. Quality of Service (QoS) guarantee requirements regarding bandwidth capacity, latency and jitter of data packet transmission or data packet loss rates are heterogeneous, depending on the specific tasks of a virtual network. Requirements for real-time transmission qualities as well as spatially differentiated data collection vary, depending on the class of applications. Not only for Voice over IP or interactive real time video games but also for a variety of application services within smart cities, very high latency requirements are key. For example, emergency centres must minimize response time so that the correct location of an accident can be reached immediately (ITU-T, 2015a: 92), networked autonomous driving requires ultra-low latency times, etc. (European Commission, 2016). Prioritization of data packets belonging to different traffic classes is required. The future challenge for data packet transmission is the change from best-effort Internet to an All-IP infrastructure with a hierarchy of quality classes with stochastic and deterministic traffic quality guarantees. Price and quality differentiation models are required to provide the economic incentives for the allocation of scarce bandwidth capacities to different traffic classes of the All-IP infrastructure capacities. Incentive compatible pricing schemes for a hierarchy of traffic classes with stochastic traffic qualities can be based on priority scheduling, taking into account interclass externalities from the higher traffic classes to the lower traffic classes (Knieps, 2011). Deterministic traffic quality guarantees require bandwidth reservations and restoration. Pricing schemes based on interclass externalities between deterministic and stochastic traffic qualities are derived in Knieps & Stocker (2016). Incentive compatible pricing for a hierarchy of deterministic traffic quality classes is analysed in Knieps (2016).

E-privacy and cybersecurity

The increasing importance of spatially differentiated real-time traffic data within smart sustainable cities causes significant challenges from a data privacy protection (e-privacy) and cyber security point of view (OECD, 2015). On one hand, the concept of open data gains increasing relevance within smart cities, enabling the machine-processable, non-proprietary and license-free use, reuse and redistribution of data. On the other hand, privacy and security concerns demand anonymization infrastructures and security guarantees within the Cyberspace (ITU, 2015b). During the last two decades, the Internet Engineering Task Force (IETF) has undertaken substantial efforts to develop security standards for IP based networks (Frankel & Krishnan, 2011), which can also be applied within IP based virtual networks for smart sustainable cities. For location-information based services (e.g. navigation applications, emergency services) the IETF has also developed an architecture for privacy-preserving in the Internet (Barnes et al., 2011).

More general rulings beyond the security of IP traffic have been issued by the European Parliament and the Council in December 2015 with the E-Privacy Regulation, repealing the data protection Directive of 1995. Among the objectives of this Regulation are easier access to one's own personal data, the right to data portability, the right to be informed whether data have been hacked, etc. More general cybersecurity objectives for "critical infrastructures" such as telecommunications, energy and transport have been considered in a Directive of the European Parliament and of the Council concerning measures to ensure a high common level of network and information security across the Union published in 2013.

Shared mobility

ICT constitutes an important driver for the increasing role of sharing activities within smart sustainable cities. One important application field is shared mobility with the move from time-scheduled organized bus services to on-demand transport provided by shared vehicle fleets of shared taxis and taxi-buses. The basic idea is that shared taxi dispatching services evolve based on real time locational optimization, taking into account the costs of additional vehicle kilometres, the opportunity costs of waiting times and the sharing preference of the users (OECD/ITF, 2016). Other use cases for shared mobility are car sharing, ride sharing, bicycle sharing or sharing of networked vehicles which are all based on real time or near-real time communication of the scarcity status at different locations within the service networks. Sharing services for bicycles and (electric) cars have gained some experience during the last decade. An illustrative example is Velib in Paris, a public bicycle sharing system with around 20000 bicycles and 1500 stations, approximately every 300 meters within the city limits (OECD, 2012: 10). In the meantime, the future role of shared self-driving cars and their impact on city traffic also gains attention. In this context, the potentials of “TaxiBots” as well as “AutoVots” are analysed. Whereas TaxiBots are self-driving cars which are shared at the same time by several users, AutoVots are similar to traditional taxi services for single users or user groups without simultaneous random sharing. The impact of these innovative sharing systems on the overall volume of cars (and subsequent congestion and pollution effects) remains uncertain, due to the future uncertainty of the substitution effects between shared vehicle services on one hand and private cars and buses (and other public transportation services) on the other hand. While results of simulation studies for the impact of sharing of taxi rides (New York), and shared self-driving vehicles (Singapore, New Jersey), are dependent on the underlying basic assumptions such as the traffic alternatives, they do suggest that significant ride-sharing potentials might exist in particular during peak hours (OECD/ITF, 2015). Sharing activities should not be confused with prosumer activities as long as the transportation services are provided by transportation enterprises. Only if sharing activities are offered as part of a non-commercial ride is car sharing a prosumer activity.

Prosumage and sharing within microgrids

An important example for prosumage combined with sharing are microgrids, which are of particular relevance for smart sustainable cities. They transform the traditional top down value chain of generation, high voltage transmission, distribution networks and local consumption household networks into bottom up local generation of renewable energy (e.g., rooftop solar PVs) within home networks, sharing this low voltage energy with different neighbouring home networks and storage of this low voltage energy with batteries or electric vehicles. Thus they combine the sustainability goal of energy policy with prosumage behaviour and sharing within the boundaries of a microgrid. Since microgrids are not self-sustaining, import or export of electricity to the distribution network or to neighbouring microgrids seems unavoidable. Although innovations regarding renewable electricity generation and battery technologies for storage outside and inside of electric vehicles are important, the large potentials of ICT are complementary necessities for the evolution of microgrids. Smart bi-directional metering, IP-based sensor networks and actuators play an important role for the design of home networks and their interconnection to the All-IP Internet. Whereas within a physical microgrid participating prosumers are balanced by an aggregator via a low voltage electricity network, the complementary virtual microgrid consists of real time information flows between prosumage units and the aggregator (Knieps, 2017).

Smart congestion management

It can be expected that prosumer activities and resultant sharing networks become increasingly relevant for the smart sustainable city of the future. However, the increasing role of prosumer activities cannot replace the role of markets for solving scarcity and congestion problems within the All-IP Internet as well as congestion problems within physical networks.

Congestion management plays a dual role in smart sustainable cities. On one hand, virtual networks can only fulfil their function to enable smart sustainable city applications if they are based on inputs from All-IP broadband network capacities endowed with active congestion management with QoS guarantees of data packet transmission. On the other hand, the use of virtual networks will reduce the transaction costs for raising usage dependent congestion fees based on the local state of congestion at different times. The implementation of congestion charges is much easier if it is supported by smart data collection appliances. An illustrative road transport case study elaborated by EGNOS demonstrates the potentials of satellite navigation services as a promising solution for electronic fee collection. Thus vehicles can be charged in accordance with the exact route they travelled, even in situations where toll gates and tolling infrastructures cannot be implemented.

From a network economic point of view, congestion pricing for network capacities in communication, transportation and electricity markets has a large welfare potential. It leads to a more efficient use of infrastructure capacities and thus reduces the need for infrastructure expansion. Moreover, toll revenues can be used to contribute to financing the infrastructure (e.g. Knieps, 2015, chapter 3).

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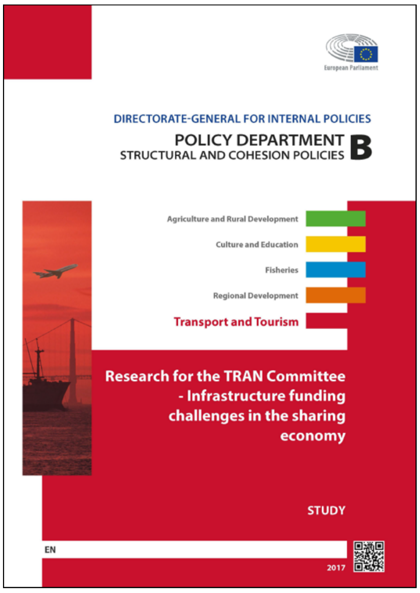

Research for the TRAN Committee - Infrastructure funding challenges in the sharing economy

Finger, Bert, Kupfer, Montero, Wolek, 2017, Research for TRAN Committee – Infrastructure funding challenges in the sharing economy, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

89 pages

About the Study

The study analyses the disruption created by shared mobility in the funding of transport infrastructure. While recognizing the benefits of shared mobility in terms of reduction of private car use, the study identifies that there might be short term negative effects on the revenues of long distance railway and coach operators. It also points out other potential risks, which include capturing the revenues through commissions charged by platforms mediating mass-transit services (Mobility as a Service), freeriding and lower tax contributions. The study makes recommendations to reduce these risks.

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The *Directorate-General for Internal Policies of the Union* is responsible for organising the work of European Parliament's committees in the field of internal policies and contributing to the exercise and development of the legislative and control powers of the European Parliament. Among its main tasks, DG IPOL is providing the committees, other parliamentary bodies and the President's Office with briefings, background notes and long-term studies on all aspects of Parliament's activities in the field of internal policies. Directorate B is the responsible one for Structural and Cohesion Policies.

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networkindustries quarterly

Network Industries Quarterly, Vol. 19, issue 4, 2017 (December)

"Public Policy and Water Regulation: Some examples from the Americas"

Presentation of the next issue

Water supply and sanitation are essential for socioeconomic and environmental sustainability. The adequate provision of these services is full of complexities and involves a great many challenges. Growing population and economic activities, plus soaring energy generation, environmental concerns, and climate change will exert great pressure on water security. It is not surprising that water has climbed to the top of the political agenda. The requirement of appropriate public policies to deal with these challenges is self-evident. Sound water regulation is a major component of this design.

The unfolding of water regulation, however, reveals a wide and complex kaleidoscope of affairs, which involve different actors, dimensions and spatial scales. Surface and groundwater provide another set of challenges in discussing water regulation. More particularly, transboundary waters – within and between countries – impose, in addition to technical challenges, the need for diplomatic skills in the proposal and development of solutions to emerging problems.

The next issue of Network Industries Quarterly (NIQ) is linked to the *Public Policy and Water Regulation International Forum*, which was organized by Tecnologico de Monterrey and Cervecería Cuauhtémoc Moctezuma – Heineken México in May 2017. The Forum had an academic framework plus perspectives from practitioners working in the field of water regulation in Latin America. Selected contributors were invited to complete this issue with its focus on the Americas.

The following are some of the themes to be included in the next NIQ:

- Regulation of water and sanitation services in Latin America
- Incorporation of natural infrastructure in water management in Latin America
- Preservation of national water resources or collection of money from users / tax payers in Mexico?
- Groundwater Regulation in Texas

Guest editor: Dr Ismael Aguilar – Barajas

(Professor, Department of Economics and Research Associate at the Water Center for Latin America and the Caribbean, Tecnologico de Monterrey, Mexico).

The guest editor of this special issue is Dr. Ismael Aguilar - Barajas (B.A.: Universidad Michoacana, Morelia, Mexico; M. Sc. and Ph. D.: The London School of Economics and Political Science). Dr. Aguilar - Barajas is a member of Mexico´s National Water Council. He was the principal editor of Water and Cities for Latin America. Challenges for Sustainable Development, published by Earthscan / Routledge in 2015. His most recent published work appears in *Journal of Physics and Chemistry of the Earth, Water International, and Water Policy.*

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