Chair of Traffic Engineering and Control
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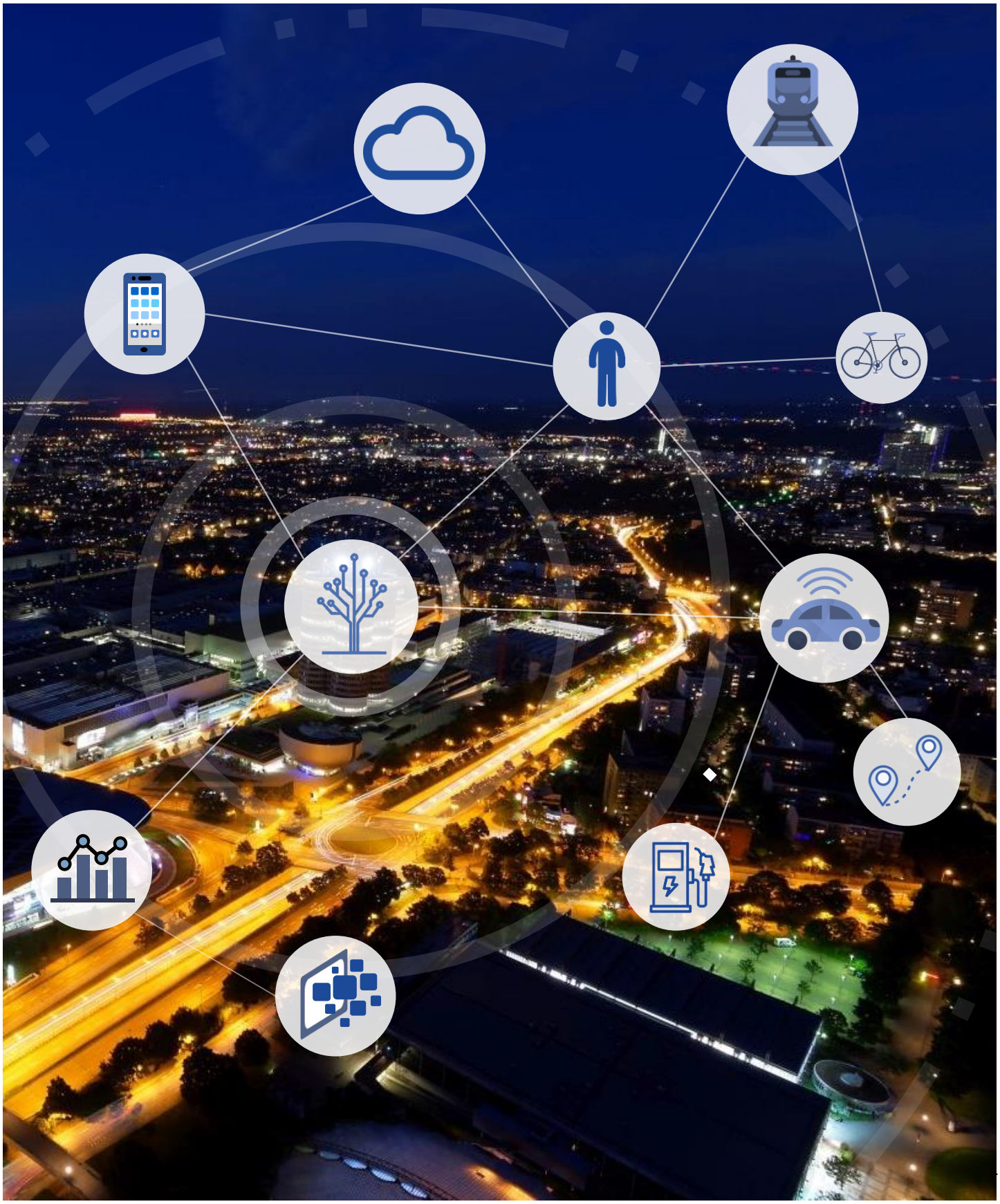
# Digital (R)evolution of ITS

## New Options for Transport through Digitalization and Big Data



This white paper has been written based on the discussions that happened during the mobil.TUM 2017 post-conference workshop on *Digital (R)evolution of ITS: new options for transport through digitalization and Big Data*. We would like to thank the workshop participants, especially to the pitching session presenters who initiated the discussions:

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# Motivation

Experts' predictions for the future of transport are of all kind, but we can certainly say that disruptive technology-driven trends will dramatically transform the landscape of mobility in the next 20 to 30 years. Digitalization and proliferation of Big Data and a variety of other factors such as sustainable policies and changing behaviour of the younger generation are gravitating the population towards pay-per-use mobility services instead of purchasing an asset upfront. Technology and communication advances have already made new mobility services possible, such as car-sharing and ride-hailing. In addition, the increasing number of smartphone users and the connected sensing technologies produce "Big Data" that provides the opportunity to better understand mobility behaviour and infrastructure performance.

For the future, it is envisioned that shared Autonomous Vehicles (AV) might reshape urban mobility, especially last mile trips in suburban regions with low accessibility. However, the changes are not limited to urban mobility. Intercity and freight transport will be facing some high-tech solutions in future. For example, Hyperloop, a breakthrough technological advancement in transport could significantly reduce the intercity travel times, and drones are to establish instant deliveries.

The confluence of these trends were thoroughly discussed in the mobil.TUM 2017 workshop: Digital (R)evolution of ITS. The workshop started with a pitching session where experts from academia, industry and authorities shared their recent experiences on key topics to ignite the discussions among the participants. Three rounds of group discussion followed the pitch session, where three main topics were brought under scrutiny:

i) users and their requirements,
ii) architecture and methodologies and
iii) solutions and technologies.

The remaining part of this document summarizes the views and findings of this workshop.

# Pitching Session

Digitalization, or in a broader sense, technology has had an immense influence on the way people and goods move around. It has opened up opportunities for more flexible forms of transport and helps travellers to make informed decisions. Using smartphone Apps for a wide range of mobility needs is becoming increasingly prevalent in our daily lives such as, real-time routing, estimated time of arrival, parking availability etc. Shared mobility, as a new way of travelling, has grown tremendously in recent years. In addition to interest in urbanism and sustainable mobility, advances in information and communication technology (ICT) have played a major role to make sharing services more efficient. In many European and North American countries, owning a car is becoming less important and people are increasingly showing interest in shared mobility. Consequently, the emerging mobility services such as car-sharing and ride-hailing are disrupting the existing transport system, especially the public transit. Furthermore, it can be seen that the automotive industry is getting ready for these changes and is shifting towards becoming a mobility provider.

The number of digital devices are far more than the number of people living in the world. On one hand, connected “things” have opened up unique opportunities for faster and more efficient interactions with users and elements of the transport system. On the other hand, they will create a virtual world that is physically disconnected from the environment around the users. AVs will be the new citizens who behave different from humans and have a complicated choice model (a black box to some extent) programmed by private companies. Admittedly, regulating the software that is affecting the road traffic is needed in addition to the regulation of the physical infrastructure. Authorities should re-think the transport system, policies and business models are to be prepared for the changes and to maintain the control of the transport system. Currently, traditional players in the transport sector have not kept the pace with the recent technological advances – which has encouraged IT companies to enter the transport market as service providers. For example, Google, Microsoft, IBM, Cisco, etc. are offering various services including but not limited to route recommendations, optimization of traffic operation, algorithms for autonomous cars, buying tickets via blockchain technology.

Another recent trend in the field of ITS is the transformation of traffic management services from hardware to software. Traffic management providers are increasingly focusing on operating a service rather than selling tools and devices. Cloud-based services are emerging as more data sources become available around the world. Connectivity, as the foundation of data-driven systems, has made real-time analysis possible without the need for a transport model. The newly offered services are less dependent on local detection systems and complicated traffic simulations. Instead, they rely on Big Data (mostly Floating Car Data, smartphone, social media etc. that globally have a similar structure) and deploy advanced analytics to enhance decision making in the dynamic traffic management process.

In essence, Big Data is a complementary part to the recent technological advances. The term Big Data is not only about the Vs (Velocity, Variety, Variability, Veracity, Value etc.). The process from which hidden patterns are unveiled and new knowledge is extracted from large and diverse data is the advantage of Big Data approaches over the traditional data management and processing. In ITS, so far, Big Data has been applied for cheaper and more efficient measurements of the same indicators for safety, mobility, operation etc. In other words, the questions are the same and Big Data is only contributing to obtain the full picture.

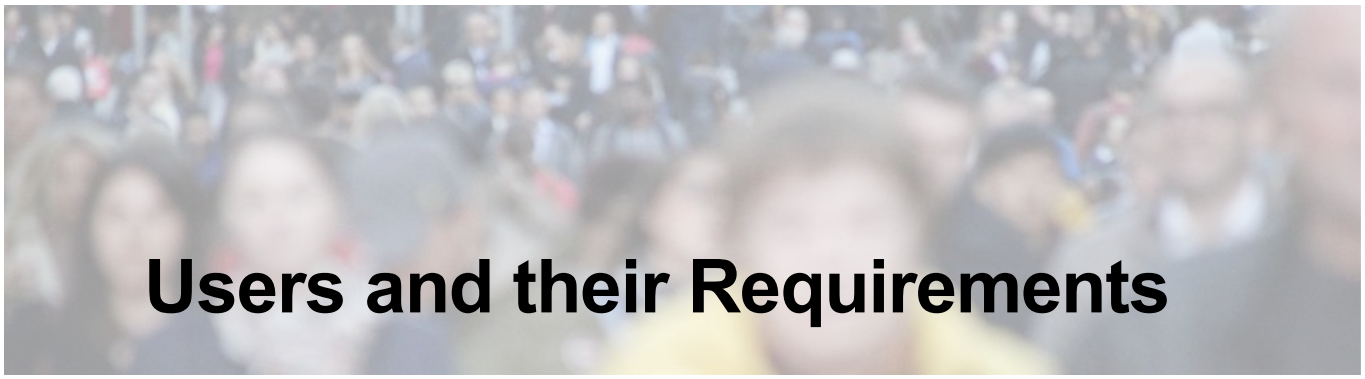
# Pitching Session

Tools and methods designed for Big Data acquisition, storage and analytics cannot fully replace the existing systems in one day. In order to exploit the advantages of Big Data in short- and mid-term, applying data fusion on both the traditional and the new data sources is the most practical approach to follow. Integrating probe vehicle data, information from various digital maps and crowd-sourced data into the existing systems promises higher accuracy and quality of the outputs that is compatible to the existing ITS infrastructure.

Despite all the expected benefits, Big Data comes with new challenges such as high computational costs, heterogeneous data in various form and structure, less explanatory power (e.g. no sociodemographic information), noisy and biased data. Machine learning (inextricably linked with Big Data) is capable of rectifying such difficulties, particularly for real-time applications. However, some other (non-technical) problems remain open including but not limited to privacy and confidentiality issues, unclear business models and value chain behind the market opportunities and the need for multidisciplinary approaches. Open data platforms seem to be an efficient solution. The benefits of such platforms are many-fold: easier data acquisition and provision, new services in traffic management, simplification of business processes, better understanding of traffic events, real-time information on supply and demand etc.

In transport sector, experts consider the data infrastructures insufficient, even though the data have significant magnitude and diversity. A review of the data value chain (from data acquisition to publishing analysis results) shows, that there are many commonalities that have resulted in developing some data platforms, which integrate data from different sources and deliver the results of the analysis (mainly short-term traffic prediction). However, some issues such as data privacy and data economy have significantly restricted the access to the data.

In the following short sections, the most important statements out of the three working group discussions are presented in concise statements.



# Users and their Requirements

The word *user* in this context is not limited to end-user (travellers). All the stakeholders i.e. authorities, urban planners, traffic control and transit operators, travellers etc. are considered as users. The discussion in this focus area was mostly narrowed down to responsibilities of each user group, the benefits of Big Data in transport and the role of authorities.

**THE ROLE OF PUBLIC AUTHORITIES:** Authorities are in charge of managing the cities and should ensure that progress is happening and the requirements are fulfilled. Services and tasks that are not profitable but are crucial to improve social inclusion such as basic mobility services in rural areas will remain in hands of public authorities. In addition, they should be prepared to deal with digital infrastructure, which currently develops at a higher pace than the standards and regulations. This makes investments from the public sector too risky and they face the question of how and where to invest to be fully prepared for the future. Another challenge is that new communities are constantly emerging with other goals than the public sector. Therefore, optimization of resources for public authorities is more important than ever, which might be seen as new models of Public Private Partnership.

**TRANSITION TO THE DIGITAL ERA:** Authorities cannot abandon their existing infrastructure overnight and adopt completely new tools. If both traditional and emerging digital data are poured in a “Data Lake”, advanced machine learning methods can guarantee that the outcome is compatible to the existing and future ITS. Moreover, the constant and rapid developments make investments from public authorities too risky. For instance, observing the profits of Big Data investments requires at least two years. This implies that high-level management should be involved in the decision making process to reduce the risks of investments.

**DIGITAL CITIZENS:** Digital services have already influenced people’s mobility behaviour e.g. departure time, route choice, using car- or bike-sharing systems etc. It is very likely that we face a new type of citizen in our daily lives! AVs will be on the streets with their own behavioural models, which is a black box designed by private companies. Therefore, it is necessary to regulate the software, which will affect the physical infrastructure.

**DATA OWNERSHIP:** The data owner (individuals, a group of enterprises or the public) must be able to decide on the terms and conditions of the use of the data. It is publicly accepted that if someone is using an infrastructure, he or she should share (part of) the data with the maintainer of that infrastructure. However, big IT corporations (e.g. Facebook, Google, Apple) have already access to the data as people have agreed to use their services. This creates an uneven competition in the market, which requires joint forces from stakeholders (car manufacturers, public transit operators etc.) if they want to stay competitive.

**REVOLUTION OR EVOLUTION:** We believe that, if the stakeholders remain the same, the envisioned landscape of mobility can be considered as an evolution of the existing system, but if new stakeholders appear, we may face a revolution, which is very likely to happen. For instance, we see energy companies interested in offering various e-mobility services, governments are handing over the ownership of important infrastructure to private sector, start-ups are actively supported to enter the market, and the number of Tech companies involved in mobility market is increasing as they see new business opportunities.

# Architecture and Methodologies

In this focus group, the discussion was mainly around the Big Data value chain and characteristics of the architecture of open data platforms. More specifics are as follows:

**THE BIG DATA IMPACT:** Until few years ago, we were seeking for data, but now data reduction methods are needed as we have plenty of useless data. Integrating new variables into the traditional models is challenging. Therefore, machine-learning methods are needed. The difference is that, unlike traditional models, we get the results first and then try to interpret the role of each variable. We can learn new relationships and interdependencies, which cannot be seen by classical statistics and by merging data from not only mobility sector but also energy, water, health etc. Nevertheless, we are still using the results as before. If the goal is to take actions and improve mobility, it is reasonable to ask if we are really benefiting from sophisticated Big Data techniques.

**OPEN DATA PLATFORM:** Shared data are the foundation of open data platforms, which not only simplify the data value chain, but also create added value through coordination among stakeholders. It should be noted that the word *open* does not necessarily refer to free access for everyone. The data ownership remains in the hands of the data provider. Despite the fact that almost everyone agrees on the benefits of data platforms, the success rate of the existing platforms is lower than the expectations. The rooting cause is not the technology: the lack of coordination and different policies to confront issues like security, privacy, data economy and ownership and trust are the bottlenecks.

**PLATFORM ARCHITECTURE:** In addition to the above-mentioned concerns, it is very important to keep the balance between business models and the architecture development. It should be flexible enough to merge with or feed other platforms if needed. Relying on standards is not always the most efficient way as they are far behind the existing technologies. Obviously, this is an inter-disciplinary task, which requires cooperation of trained people with mixed profiles from economy to software engineering. The existing ITS- and sw-engineering architectures are a good starting point for a bottom-up approach.

**PLATFORM GOVERNANCE:** Centralized governance, in which one entity is assigned with the task of a continuous supervision of the system, is not realistic. Such role is beyond the capabilities of public authorities and if it is granted to the private sector, it creates a conflict of interests. Perhaps, a decentralized approach, where the roles will be mutually assigned depending on the use case, seems to be a more practical path to follow.

**USE CASE AND USER CENTRIC DEVELOPMENT:** There is no single method that could be globally accepted for all use cases. Depending on the use case, the data analytics methods, the prediction accuracy and their associated risks may vary. However, the outcome must fulfil the requirements and must be understandable for the user. In most cases, the architecture of the backend is not of interest for the users. They value a consistent interface.

**INCENTIVES AND MIDDLEWARE:** Public authorities should promote middleware that enables all the stakeholders to test and evaluate their methods. A testbed where stakeholders can share and learn from each other is more valuable than supporting one product/approach, because at the end of the day there will not be one global solution. One successful experience is the preparation of the NGSIM[1] dataset, where many simulation tools were tested and improved using the publically available data.

[1] https://ops.fhwa.dot.gov/trafficanalysistools/ngsim.htm

# Solutions and Technologies

This group was focusing on the emerging services and solutions that became available mainly due to the advent of smartphones. New modes of travel such as AVs and sharing mobility are the trends that have been thoroughly discussed in this working group.

**NEW TRANSPORT OPTIONS:** An essential requirement for modern transport systems is that it provides the users with an extensive list of options scaled to their needs. In recent years, a wide variety of factors including technological, economic and environmental forces have given rise to a number of new transport options: car- and bike-sharing, ride hailing, on-demand public transport etc. These options are normally a completion to the existing modes, mostly public transit. Such trip chains that involve more than one mode have created a concept called Mobility as a Service (MaaS), which is discussed in more detail below. One may also think about virtual mobility (VM) which replaces physical mobility. Nowadays the possibilities to implement effective solutions for VM are far more powerful than in the older times when so-called "Tele-Working" was promoted and did not really succeed.

**MOBILITY AS A SERVICE:** MaaS offers a diverse list of transport options with single payment method. The main goal is to improve the user's experience and to create opportunities to serve unmet demand. In junction with sharing economy, MaaS paves the way towards a pay-per-use mobility service. People are likely to adapt to MaaS, which probably comes to their hands in form of a smartphone App, if they experience seamless journeys and a user-friendly interface. Successful examples in setting de facto standard for App interface are Uber and Google maps. However, some questions remain open: how should the interface look like? Who has access to the data? How should the system be operated and maintained?

**AUTONOMOUS VEHICLES:** It is certain that AVs will enter the market in the future. It is generally believed that they improve overall mobility i.e. reduce congestion and increase safety. Reducing congestion will only become true, if we have very high penetration and maybe some legal push or constraints for normal and non-shared vehicles; otherwise, we will run into more congestion and less efficient use of the existing road infrastructure. Maybe the general access to the connected and multi-/inter-modal transport system becomes easier, smarter and seamless, because of more automated transport services…However, we should not give up the urban space and the physical infrastructure to autonomous vehicles. Walking and cycling ensure liveable neighbourhoods and must be promoted as well. There are some other risks attached to AVs. For example, public transit is going to be affected with the introduction of fleets of AVs (e.g. automated taxi fleets). A new ***individualized public transit*** that is located between the current public and private transport could arise. Regulations are needed to avoid having cities packed with AVs.

**REAL-TIME TRAFFIC PREDICTION:** Big Data is increasingly improving transport-related models because models were conditioned by the available data at the time they were developed. Real-time traffic predictions have been possible through the implementation of machine-learning methods (inextricably linked with Big Data). Integrating new variables into traditional models is challenging. Therefore, machine-learning methods are needed to really use the new variable. In data-driven approaches, unlike the traditional models, the role of each variable is interpreted by analysing the outcome. Furthermore, Big Data could also be used for the automation of model maintenance i.e. continuous calibration and validation. In specific cases, data-driven methods indicate superior results in comparison to model-based approaches. However, the lack of training data in some situations e.g. anomalies in traffic condition, deviates the results of machine-learning from reality. Admittedly, a hybrid solution where both data-driven and model-based methods are used will guarantee the quality of the outcomes.

# Key Takeaways

Below, we briefly point out the most important takeaways of the workshop to be considered for future activities:

- Public authorities remain responsible for managing the physical infrastructure. They should provide the necessary testbeds and middleware for the private sector to assess innovative solutions. Regulating the software that controls AVs is required to ensure citizens safety and prosperity.

- Open data platforms are one of the available solutions for sharing Big Data. As the size of the digital universe grows, the need for plug-and-play platforms becomes more vivid.

- Technology is not the bottleneck that prevents the utilization of Big Data. Policies and concerns on data privacy, security and economy are the hurdles, which reduce access to the data. A bottom-up decentralized data governance policy, where stakeholders mutually agree on the rules is the most practical solution.

- Even though mobility and user behaviour have an influence on technological advances, in most cases technologies are driven by other domains and markets e.g. commerce, logistics, gaming. Admittedly, mobility solutions probably in most cases are piggyback on other mainstream developments.

- Sophisticated technologies and complicated analytics without a positive influence on mobility are not a solution to problems. We must guarantee a balance between technologies, business models and policies to achieve improvements.

- People will adapt to new technologies and mobility solutions e.g. MaaS if the frontend interface is user-friendly. Perhaps one of the reasons Google Maps is globally accepted is the fact that *the world looks the same in Google Maps.*

- There is no unique model for future cities. They will retain their individuality while adopting new technologies. However, we believe that rail bound transport remains the backbone of the future transport systems. New transport options (e.g. on-demand shared mobility) will act as feeder for public transit and solve the first- and last mile problems.