A Conceptual Framework for the Interactions of Autonomous Public Transport Systems and Urban Planning Guidelines

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Conference paper STRC 2016

STRC

16th Swiss Transport Research Conference

Monte Verità / Ascona, May 18-20, 2016

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May 2016

Abstract

This PhD research aims to construct a platform for the study of interactions between autonomous public and private transportation systems and the guidelines of urban, spatial and land use planning from the transportation systems point of view. This project will identify revised and new guidelines of urban planning that will be caused by the disruptive changes in public transportation systems through their automation and driverless operations.

The significance of this research for science, society and practice can be summarized in its efforts to identify the policy guidelines of land use, urban and spatial planning which will be relevant for the future of public transportation systems with automated operation and autonomous vehicles. The new or revised guidelines will serve as the inputs for further development of urban planning principles from the transportation point of view. Additionally, this PhD research is of high significance to the rail transport industry, namely SBB, DB, ÖBB, SNCF, etc. since this research will assist the rail transport to keep its competitive position by considering the options to build a cooperation platform with autonomous vehicles such as autonomous buses and minibuses as well as automated ride sharing and free floating car sharing with autonomous cars.

Keywords

Autonomous vehicles – Public transport systems – Urban planning guidelines – Autonomous public transport systems – Spatial and land use planning

1. Introduction

On the one hand, for many decades, public transport services have been in fierce competition with private road transport. Urban planners and decision makers, in cooperation with transport experts, always try to come up with measures to encourage people to make more use of sustainable forms of transport including non-motorized (walking and cycling) and motorized (bus, tram and train) transport; and therefore, to shift the travel demand from private to public modes of transportation.

On the other hand, there has been an established system of cooperation between public and private transportation systems, meaning that private cars, as well as bicycles serve as last mile feeders to and from the public transport stations. Large Park and Ride (P+R) lots, especially at peripheral train stations as well as Bike and Ride (B+R) facilities are proofs and facilitators of this cooperation. By enabling the door-to-door transport and together with walking and cycling, private vehicles play the role of last links in our daily mobility chains.

Besides the interactions between different forms of transportation systems, there is another type of interaction in a wider sense, which is the interactions between the built environment and transport systems. Meaning that, the transportation systems we observe today, are influenced by the physical forms of the cities they serve. Conditions such as urban topography, size, population, etc. dictate specific conditions for the transport systems.

Furthermore, in order for a public transport system to function properly and efficiently in an area, certain requirements on land use and spatial characteristics have to meet. For instance, special requirements on population densities or walking distances in its catchment areas should be fulfilled, so that it can operate successfully and function economically by attracting high numbers of residents.

Up until now, the conventional forms of transport systems, including private, public and shared systems, in which the vehicles are driven and controlled by human drivers, have dominated our streets and shaped the forms of our cities and agglomerations. However, this might change by the emergence of autonomous vehicles, since the industry is investing large sums in order to bring such cars to the market. As one might expect, the ease of use and the elimination of barriers to access such vehicles, such as no further need for a driver's license and enabling the elderly and people with reduced mobility to have access to public transport services will change

the market and its properties extensively. Furthermore, the providers of public transport services could benefit to a large extent from the fact that they can operate their services without the need for drivers. This will result in considerable savings in personnel costs.

2. State of research

The topics of autonomous vehicles (AVs) and autonomous driving are not new in nature, but thanks to recent accelerated technological innovations and breakthroughs, they have become the center of attention in recent years. Since the introduction of first driverless cart by the university of Stanford "Stanford Cart" (Earnest, 2012), up to the state of the art vehicles of Mercedes Benz and Tesla Motors as well as Google pods, the main research topics were related to those of technological and engineering requirements. Only in recent years, the topic of Autonomous vehicles has grabbed the attention of researchers from various fields such as environmental studies, social scientists, psychologists and transportation engineers and planners. Especially in recent years the impacts of AVs on public transport systems and the possible uprising competition and cooperation between AVs and public transport, have become the topics of interest.

Freemark (2015) argues that autonomous vehicles will result in reformulation of today's transportation and will radically expand mobility.

A study conducted by Cisco revealed that half of world's consumers would trust and be willing to ride in an autonomous vehicle (Carter, 2013) this share might even increase, once the AVs have penetrated the market and their benefits in terms of utility are known to the public. One utility associated with AVs is the productive time inside them. It is now clear that the productive attribute of travel can impact its utility and participating in productive actions such as reading, writing and working in a vehicle can notably impact utility and result in a small but non-marginal fraction of today's mode shares (Malokin et al., 2015).

Besides the ongoing research for AVs as private cars, parallel scientific research works are ongoing for their utilization as public transport vehicles. The Project CityMobil2 is one of the most prominent of those in Europe. Initiated by CTL[1] and co-funded by European commission, CityMobil2 test runs automated road transport systems in several European cities, including the EPFL campus in Lausanne ("CityMobil2," 2012, "Citymobil2, EPFL," 2012). Alessandrini, et al. (2015) investigate alternative autonomous mobility scenarios in the framework of

[1] Research Center for Transport and Logistics, University of Rome

CityMobil2 project, including both niche and large-market innovations and their consequences on European cities and their transport systems. In their paper, they present an overarching overview of AVs, including different vehicle sizes and settings with different levels of automations for various application case, as well as different ownership and sharing concepts. However, they asses the impacts on European cities form the Passenger Application Matrix (PAM) vision and not land use or spatial planning point of view. In the concept of PAM, they categorize the settlement structure into five categories of City centers, Inner suburbs, Outer suburbs, Suburban centers and Major facilities and evaluate the effectiveness levels of different types of AVs for each of these settlement categories. Another research project concerning the utilization of autonomous vehicles in public transport operations is the joint research project between EPL, the startup company BestMile and PostAuto Switzerland (Brouet, 2015). PostAuto launched its first autonomous shuttle test runs in December 2015 in Sion, Switzerland (Figure 1) and provided that the special permits are granted from responsible authorities, it is expected that from Spring 2016, they will be transporting passengers on the roads (PostAuto, 2015).

Figure 1 Autonomous shuttle in Sion

Source: postauto.ch

In recent years, and due to increased attention to automation and the applications of AVs in private, semi-private and public transport systems, the *Swiss Federal Railways (SBB)* has given considerable attention to the topics of automation of railway operations and the application of autonomous vehicles in public transport systems. In contrast to a general opinion that

autonomous vehicles could be rivals for the railways, Andreas Meyer, the CEO of SBB, has expressed his visions in seeing AVs as an opportunity for the SBB and for the public transport systems, rather than a risk (Ehrbar & Müller, 2015; Schittler, 2015). He calls the new market with autonomous vehicles as *"Public individual transport"* with the implication for the customers that (Schittler, 2015):

> "They [people] can travel with a public transport vehicle and without an own car in a door to door form."

Up until now, the topic of interactions of autonomous vehicles and land use, urban and spatial planning has seen little attention from scientific society. In available papers and literature regarding autonomous vehicles, rarely the topics of land use, urban and spatial planning have been covered and if covered, only in a form of general assumptions and guidelines and not in-depth analyses and assessments. For instance, Mineta Transportation institute in their report on Automated Transit Networks (ATN) present guidelines and measure on how to accommodate guideways for ATN in our existing city street networks (Furman et al., 2014).

2.1 Research Gap

Although there are numerous finalized and ongoing research projects regarding different aspects of autonomous vehicles, including their technological structures, legal frameworks, policy implications, etc., up until now, there has been no work done which investigates the automation of transport systems with public, private and shared vehicles in an integrated way with respect to spatial und urban planning.

The consequences of automation of transportation systems on the expected changes in planning guidelines and from the transport systems' point of view is a novel approach which has not been covered in any scientific research.

3. Research question

Today, the cost function is the most prominent influencing factors in the operation of public transport systems. Among the elements of the cost function, clearly the labor costs play the most crucial role, which to a high extent are comprised of the driver wages (Intraplan Consult & VWI Verkehrswissenschaftliches Institut, 2009; Leuthardt, 2005, 2010).
That is to say, resulting from this strong cost dependency and in order to reduce total operational costs and to maximize efficiency, there is the tendency to bundle the demand for public transport. This tendency is more noticeable in areas with sparse networks with not very dense timetables.

Due to this resulting capacity problem in opening up of the areas, urban planning has to follow several rules to concentrate settlements around public transport facilities.

As one main consequence of the autonomous vehicles is the elimination of the need for drivers, one can argue that due to the future changes in cost function by the elimination of driver wages, the significance of demand bundling fades away and consequently, the guidelines for settlement developments might change, undergo a revision or loosen up from the transportation point of view.

Driven from these arguments, the overarching question for this research project is as follows:

Does the automation of public transport and last mile services lead to revised guidelines of land use, spatial and urban planning, from the transport systems point of view?

3.1 Hypotheses and Sub-questions

The following sub-questions and corresponding hypotheses are defined for the main research question:

- **Q1** *What urban, spatial and land use planning guidelines are supported today and how are they linked to current transport systems?*
    - **H1.1:** The functional characteristics of today's transportation systems impose special requirements on land use and spatial planning in cities of today.

- **H1.2:** The requirements of today's transport systems on land use have resulted in some guidelines of land use, spatial and urban planning.

- **Q2** *What forms of transport systems are expected in long term?*
  - **H2:** The automation will affect not only the private cars; the public transport vehicles including trains, trams and buses, as well as last mile feeder systems will also be automated. New forms of car sharing with autonomous cars, such as *free floating car sharing (FFC)* are also expected.
- **Q3** *Which features and characteristics of public transport systems will change due to full automation?*
  - **H3.1:** Due to the automation of public transport services, it will be possible to transport small number of passengers in an economic way.
  - **H3.2:** In contrast to the fleets of today, more intermediate vehicle sizes and consequently, more demand-oriented capacity utilizations are expected in road public transport as a result of the automation.
- **Q4** *What are the outcomes of special characteristics of autonomous transport systems from urban planning and land use point of view?*
  - **H4:** Different functional characteristics of autonomous public transport systems will cause changes in their requirements on land use. The optimal settlement structures in the future will be driven less from today's characteristics of public transport systems with sparse networks, but more from other parameters, such as energy or space consumption.
- **Q5** *In what manner will revised planning guidelines arise from the specific characteristics of autonomous transport systems?*
  - **H5**: Altered requirements of autonomous transportation on land use will revise those guidelines of land use, urban and spatial planning which are valid for today and new guidelines will arise do to the automation.
- **Q6** *What will be the consequences of revised and new planning guidelines on the future cities?*
  - **H6**: The new and revised planning guidelines will have noticeable impacts on the land use in the cities of future.

4. Detailed Research Plan

4.1 Work packages

WP1: Introduction, research question, Literature review, hypotheses

An intensive review of literature is foreseen is this WP to study what is already available and missing in scientific research. Valid findings and conclusions will be taken as the basis of the research and sound methodologies will be identified for the carry-out of the research.

In this work package, there will be a deepened literature review in the sense of research question.

WP2: Identification of spatial and urban planning guidelines induced by the requirements of transportation systems on land use (today's situation)

WP 2.1: In Work package 2.1, the transportation systems of today will be analyzed from the point of view of functionalities in different settlement types (cities, agglomerations, etc.). The efforts will be given to find out what today's transport systems require in different settlement structures, so that those systems can operate efficiently (H1.1).

WP 2.2: In next step it will be analyzed what urban, spatial and land use policy guidelines exist today that are resulted from such requirements (H1.2).

In other words, today's planning guidelines that exist due to the characteristics of current transportation systems, will be identified and listed.

WP3: Development of spatial and urban planning guidelines induced by the characteristics of future automated transportation systems (future situation)

WP 3.1: First, the functional attributes of transportation systems in case of full automation including public, private and shared systems have to be defined (H2, H3.1, H3.2). From those characteristics, the new requirements of automated transportation systems on land use will then be identified (H4).

WP 3.2: In second part of work package 3, the new planning guidelines will be developed that will be valid for the new automated transportation systems (H4, H5).

In other words, efforts will be given to:

- First, identify the changes in characteristics of public transport systems with autonomous vehicles
- Second, to determine the effects of changes in transport system on land use planning regulations

The outcome from WP 2 and WP3 will be a catalog which lists all the land use, urban and spatial planning guidelines which are valid for the transport systems of today and future. Through this catalog of guidelines, the comparison between existing and new guidelines can be done and the similarities and changes in those guidelines can be determined.

WP4: Implication of new planning guidelines on the land use and urban forms (conceptual)

As the last step in research before the carry out of cases studies, in WP4 the efforts will be given to conceptually determine the impacts of newly developed guidelines on land use and urban forms in a model region with a generic settlement structure. For instance, if density loses its importance in the cities of future with automated transport systems and then the urban planners are no longer required to design compact and dense cities, then what consequences these will have on the spatial forms (H6).

WP5: Case studies, proof of concept

In the work package for case studies and proof of concept, the impacts of revised and new planning guidelines will be tested in selected case studies. That is to say, to find out if the findings in WP4 regarding the changes in urban forms due to new planning guidelines, will conform in real study areas if those guidelines are adopted and applied.

WP6: Synthesis and conclusions

The outcome from this final WP, besides the dissertation report, will be the new policy guidelines for the future where the transportation systems are automated and function in an integrated way with autonomous buses, trains, trams and autonomous cars as private and also shared vehicles.

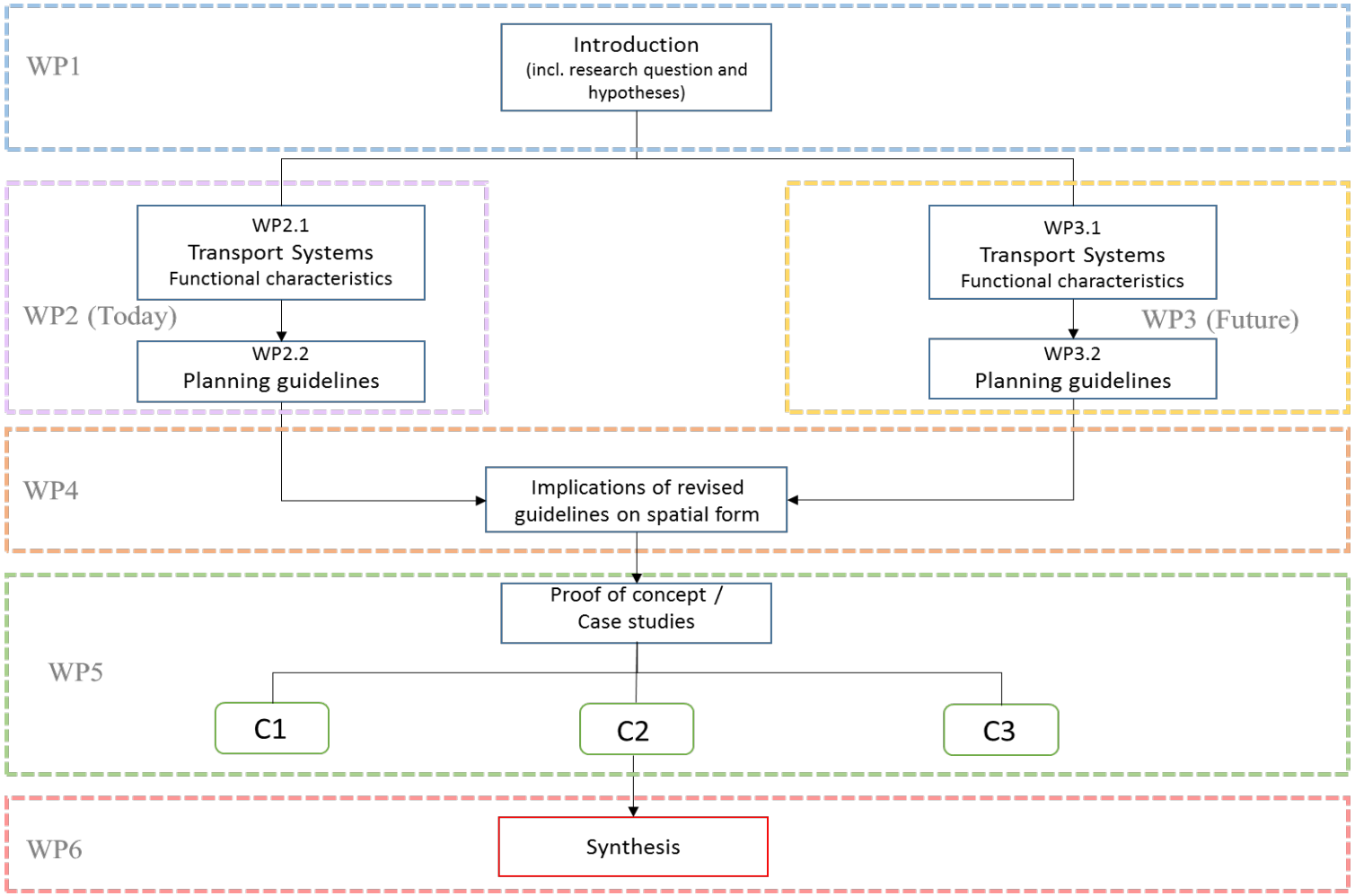
Also a general outlook which presents the shape and spatial forms of future cities, if such guidelines are enacted, will be available.

These guidelines, will serve lawmakers, urban and spatial planners in making timely decisions to prepare our settlement areas for the autonomous vehicles before it gets too late. This will help them to maintain the livability of our cities for us and for the next generations.

Additionally, the guidelines catalog will serve to depict the similarities and changes in land use and spatial planning guidelines for current and also future automated transportation systems.

A schematic workflow of the research and the logical interrelations between work packages are depicted in Figure 2.

Figure 2 Schematic workflow of the research



4.2 Foreseen Methodologies

The following methodologies are foreseen for each of the work packages:

- **WP1 (Introduction):** Literature review, expert interviews, brainstorming
- **WP2 (Transport systems and land use – today):** literature review, case studies with possible GIS spatial analyses, statistical analyses of settlements (precise data on population, density, etc. required), study of historic development of cities and transportation offers, study of different planning ideas (TOD, smart growth, etc.)
- **WP3 (Transport systems and land use – future):** literature analysis on emerging technologies in AVs, expert interviews and estimations, brainstorming, study of possible changes in the characteristics of public transport systems and estimating the plausible trends
- **WP4 (implications of new planning guidelines):** study of available guidelines in different planning ideas, urban planning regulations, zoning and land use development plans, interactions model between the existing requirements and guidelines, interactions model between the revised requirements and guidelines
- **WP5 (Case studies, Proof of concepts)**
  In selecting the cases to study, attention will be given to include different settlement types, including cities, agglomerations, urban suburbs, towns, etc. inside Switzerland and also from the European cities from Germany, France, UK, Austria, etc.
  The application of new or revised principles to the selected areas can be done using GIS models, for which data regarding population, car ownership, transportation mode shares, built up area and available land are required

The listed methodologies are not inclusive and through the advancement of the PhD research, further methodologies could be applied.

5. Conclusion and Outlook

This PhD research will contribute to the understanding of interactions between the features of public transport systems and planning regulations by investigating the disruptive changes in public transportation. It is expected that this research identifies the policy guidelines of land use, urban and spatial planning which are relevant for transportation systems of today and those guidelines which will keep being relevant or the new guidelines that will become relevant after the emergence of autonomous vehicles and automated transport systems. Only then, the possible negative, as well as favorable impacts of these new transport systems on built environment can be identified.

The new insights enable urban and spatial planners, designers, policy makers, legal authorities, providers of public transport services, etc. to implement their plans and designs and provide their services in a way, that not only the sustainability of future cities are ensured, but also they turn to be more livable with higher vibrancy, higher safety levels, public health and less energy consumption with cleaner climates.

In addition, rail companies, namely SBB and the similar companies in Europe, such as Deutsche Bahn, SNCF, ÖBB, etc. are of high importance as one of the core topics of this research is to come up with ideas and measures, so that rail companies can stay competitive in a future where whole land transport systems are automatized. This goal will be fulfilled by measure that on the one hand, keep rail transport attractive to passengers and economical to run for the operators and on the other hand, utilize the positive effects of autonomous vehicles, and apply them as a part of their services.

This research merely deals with the guideline of land use, urban and spatial planning from the point of view of transportation systems and excludes the internal interactions within urban regions and settlements. The technological preconditions and necessities for autonomous vehicles are also neglected and the assumption is that such vehicles are available in our research environment. The penetration rate of such vehicle into market is presumed to be 100%.

The revised or new guidelines which are to be determined in this PhD dissertation, are not intended to be the key planning principles, but rather the inputs for further development of urban planning principles merely from the transport systems point of view.

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