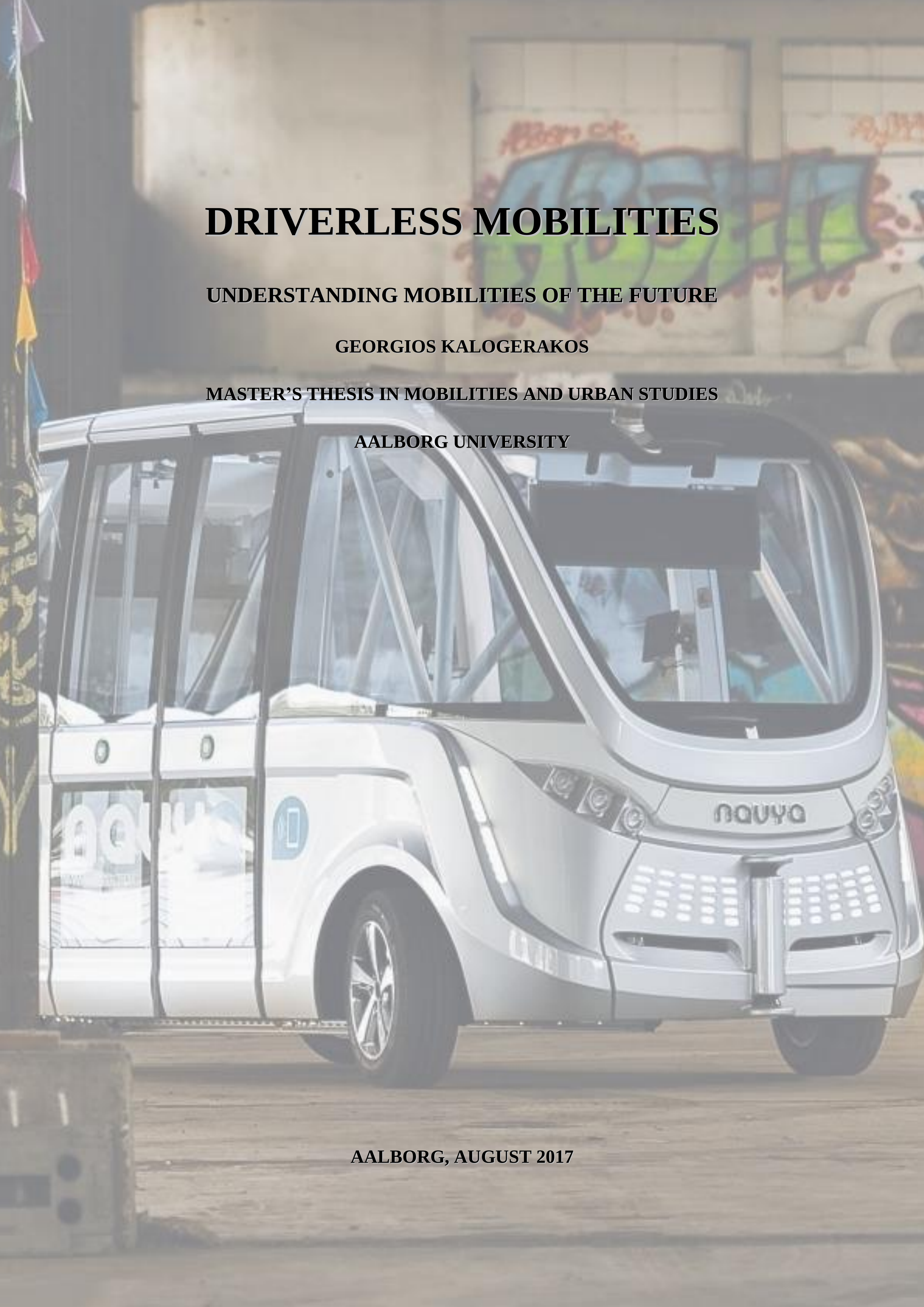


DRIVERLESS MOBILITIES

UNDERSTANDING MOBILITIES OF THE FUTURE

GEORGIOS KALOGERAKOS

MASTER’S THESIS IN MOBILITIES AND URBAN STUDIES

AALBORG UNIVERSITY

AALBORG, AUGUST 2017

Aalborg University

The Technical Faculty of IT and Design

School of Architecture, Design and Planning

Master's Programme in Mobilities and Urban Studies

Thesis title: Driverless Mobilities: Understanding Mobilities of the Future

Georgios Kalogerakos

Supervisor: Assoc. Prof. Claus Lassen

Submission: 15 August 2017

Cover photo: Navya Arma driverless bus. Source: http://navya.tech/wp-content/uploads/2015/09/W1A6487-print16-0.jpg

Synopsis

Mobilities are being greatly reshaped in order to respond to contemporary challenges, such as automobile dependence, environmental pollution and so on. Mobilities performed by Autonomous Vehicles (AV), or driverless mobilities, will play a leading role in this process due to the vast array of new possibilities they may bring. In particular, this technology will bring a sharp decrease in the overall cost of mobilities system, including their spatial, social, environmental etc. negative externalities, and notably contribute to their optimization. However, since their implementation is at a rather immature stage, many aspects including, but not limited to their potential effects, technological readiness, legal issues, ethics and societal acceptance are still largely undiscovered. Aim of this project is to elaborate on the future modus operandi of driverless mobilities, as well as to identify which are the supportive driving forces and the challenges in their implementation. Examination of two cases where driverless mobilities have been practiced, in Aalborg, Denmark and Trikala, Greece, pointed out a strong impact of three elements in making driverless mobilities. Safety goes first. Embodiment of AV into existing mobilities practices will be impossible if actual and perceived levels of safety are not high enough. Then come two factors of equal importance, namely proof of usefulness and perception of people towards them.

Key words: Driverless mobilities, last mile problem, Autonomous Vehicles, Demand-Responsive Transit, case analysis

Acknowledgements

First and foremost, I would like to express my sincerest gratitude to my supervisor Associate Professor Claus Lassen for his invaluable guidance and support through the process of researching and writing my thesis and throughout the years of study as well; I am so grateful for all I have learned from him in his courses. Moreover, I am particularly grateful to the experts I consulted Mrs. Mette Skamris Holm, Mr. Martin Kyed, Mr. Nicolai Bernt Sørensen, Mr. Andreas Egense, Mr. Dennis Lange, Mr. Odysseas Raptis, Mrs. Christina Karaberi and Mr. Loukas Vavitsas (job titles on page 15) for their precious contribution to the completion of my thesis. Furthermore, this project is only one of the things I owe to the continuous support and encouragement of my family, Maria and my friends who deserve my warmest thanks.

TABLE OF CONTENTS

List of Abbreviations

AAU: Aalborg University

ACC: Adaptive Cruise Control

ADAS: Advanced Driving Assistance Systems

ARTS: Automated Road Transport Systems

AV: Autonomous Vehicles

BCR: Benefit-Cost Ratio

BRT: Bus Rapid Transit

CBD: Central Business District

CIAM: International Congress on Modern Architecture

CMU: Carnegie Mellon University

DARPA: Defense Advanced Research Projects Agency

DKK: Danish Krones

DRT: Demand Responsive Transit

EU: European Union

FDM: Federation of Danish Motorists

GCRT: Geneva Convention on Road Traffic

GIS: Geographic Information System

GRT: Group Rapid Transit

ICF: Intelligent Community Forum

ICSS: Institute of Communication and Computer Systems

IDA: Danish Society of Engineers

KOK: Greek Highway Code

LKA: Lane Keeping Assist

MD: Ministerial Decree

MPM: Morgantown People Mover

NHTSA: United States National Highway Traffic Safety Administration of the United States

NT: Northern Jutland Transport Authority

NTUA: National Technical University of Athens

PRT: Personal Rapid Transit

PT: Public transport

SAE: Society of Automotive Engineers

SCAFT: City Building, Chalmers, Working Group for Traffic Safety

SP: Stated Preference

SUMP: Sustainable Urban Mobility Plan

TACC: Traffic-Aware Cruise Control

TOD: Transit-Oriented Development

UAE: United Arab Emirates

UHF: Ultra High Frequency

UK: United Kingdom

UNECE: United Nations Economic Commission for Europe

V2I: Vehicle to Infrastructure

V2V: Vehicle to Vehicle

V2X: Vehicle to everything

VCRT: Vienna Convention on Road Traffic

VHF: Very High Frequency

VMT: Vehicle Miles Travelled

WVU: West Virginia University

List of figures, images and tables

Figures

Images

<u>Tables</u>

1. INTRODUCTION

Mobilities are under constant reform, in order for higher levels of sustainability to be achieved. In particular, they should conform with the steadily increasing demand for reduced costs, increased flexibility, lower car dependency and redistribution of urban space for the benefit of active transport. Public Transport (PT) is of great importance for this transition; nonetheless, in many cases it features an amount of weaknesses, such as limited flexibility, high operational costs and lower efficiency, particularly in sparsely built areas. On the other side, some car-based alternatives like car-sharing and car-pooling can also contribute to the process of making mobilities more sustainable, by reducing the amount of cars on the roads and supplement PT, in insufficiently served areas. However, it is questionable to which extent expansion of those alternatives will be beneficial for the marathon of making mobilities sustainable or will just compete with PT and crowd urban centres with more vehicles. Active transport is another critical alternative form of mobility with numerous benefits for both society as a whole and mobilities agents individually; yet its potentials are by nature limited. Therefore, renegotiation of the role of alternative forms of mobilities as well as conceptualization of new forms should take place. New forms should address challenges that are not being answered by existing mobilities systems and supplement them in order to make mobilities more holistic, effective and sustainable. Autonomous Vehicles (AV) are a forthcoming form of mobilities and can be an inherent part of future mobilities due the uncountable benefits they embed. This is first because their major economic advantage the lack of driver, and second because constant networking with their surroundings will enable routing optimization, leading to unforeseen economic, environmental etc. savings (Dennis and Urry, 2009). Under this prism, this project constitutes an effort to investigate the philosophy of this upcoming form of mobilities, by examining its *logic* (Lassen, 2009 in Jensen and Lassen, 2011) and its implementation driving forces. In this project, that will take place through first review of existing theoretical and empirical evidence in the field and second through the examination of two outstanding - “first mover” - applications of driverless mobilities. This way, both current progress of academia, power and institutions in adopting this new technology in their agenda will be depicted; and knowledge on how they are being materialized will be gained. Aforementioned issues will be examined on the basis of the following research question:

How will driverless mobilities shape mobilities of the future?

Which is articulated in the following sub-questions:

How could driverless mobilities be understood and defined?

Which are the supporting driving forces as well as the challenges in the establishment of driverless mobilities?

How long will it take for the full transition of mobilities to the fully driverless era?

Main body of this project is unfolded in three chapters, namely defining driverless mobilities; history and development of driverless mobilities; and driverless mobilities in practice: evidence from Aalborg east, Denmark and Trikala, Greece. In the first chapter, the basis of the answer of the first research sub-question is formed, so that it will become clear which is the meaning and the foundation of this form of mobilities. Afterwards, in the second chapter, the deployment of driverless mobilities over time is illustrated, while an analysis of their modus operandi takes place. Then, in the third chapter the examination of the two outstanding cases where driverless mobilities have been or are about to be deployed takes place. First, neighborhood mobilities in Aalborg East, are studied while second, a driverless bus demonstration in Trikala, Greece, is researched. At the end of this chapter conditions, parameters and meaning of both cases are reviewed, leading to final conclusions of the projects, where it is endeavored to answer aforementioned research questions.

2. METHODOLOGY

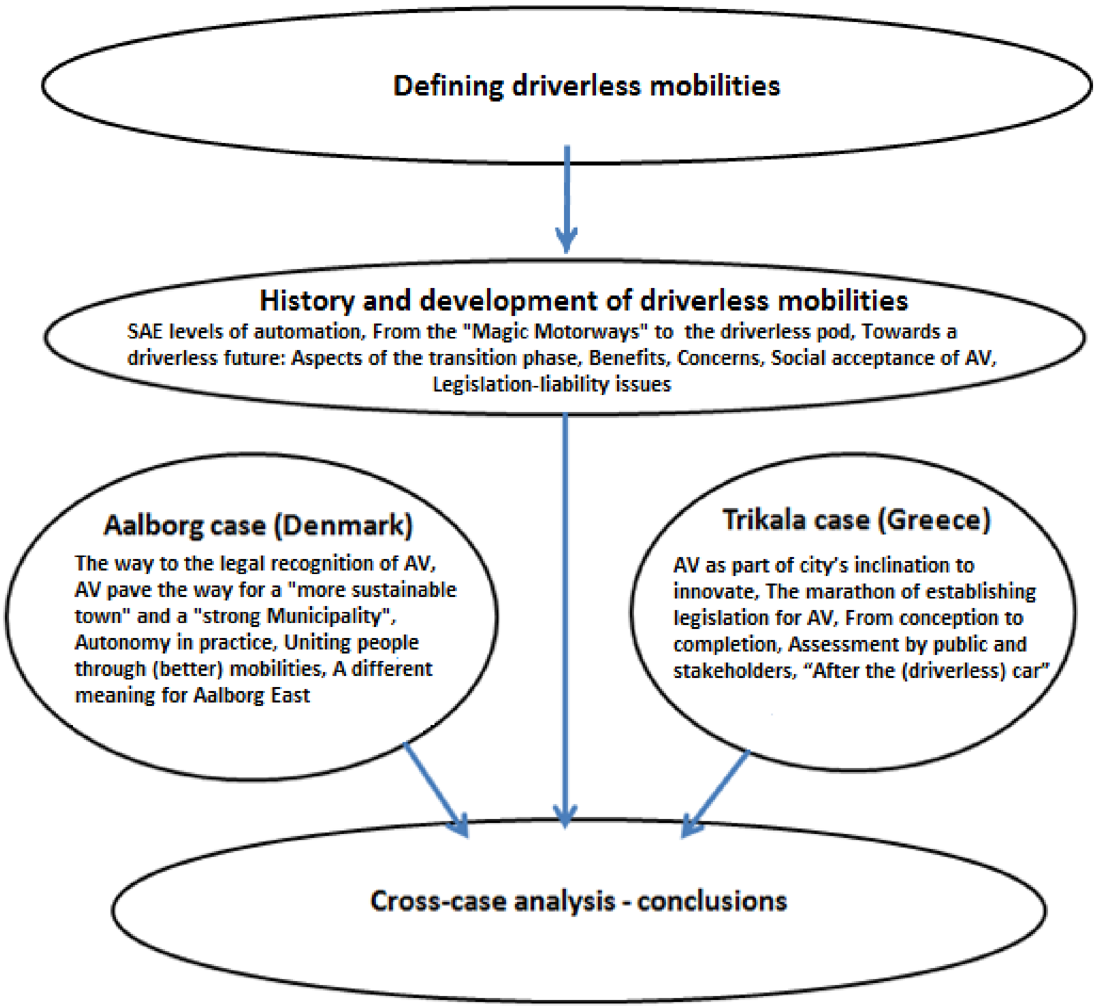
2.1.Philosophy of science

Driverless mobilities in this project are analyzed using the tradition of pragmatism, as object-based holistic approach is chosen. This approach allows detailed and interdisciplinary exploration of all aspects of this new mobilities system, providing useful knowledge on how it affects other domains (place, society etc.) as well as how it is affected by them. Since driverless mobilities are, as mentioned before, a completely new and largely unknown system, gaining awareness of its meaning requires rich understanding of its components and vice versa. This process is described as the "Hermeneutics circle" (C. Hoy, 1993 p. 172). Moreover, empirical-analytical perspective is also one of the chosen in this project. This is because a large part of the evidence used comes from the research upon the two selected cases, where driverless mobilities have been or are about to be practiced, in Aalborg, Denmark and Trikala, Greece.

2.2.Methodological framework

The methodological framework of this project includes review of existing literature regarding the implementation of driverless mobilities and their potential role in the mobilities system, interviews with relative key stakeholders as well as the examination of the two aforementioned cases in Aalborg, Denmark and Trikala, Greece. Literature review was necessary in order to learn about potential benefits and concerns of driverless mobilities, as well as to gain knowledge on the extent this new form of mobilities is implemented, accepted by society and legally acknowledged. Then, analysis of two cases, where both kind of implemented driverless mobilities (unmanned/manned vehicle etc.) and overall environment (kind of traffic etc.) are greatly deviant provided an insight on if, and which way, whatever is stated in theory is practically possible.

Figure 1: Structure of the project



Source: own illustration

2.3.Literature review

In this part of the project extensive investigation of available theoretical and empirical scientific evidence about driverless mobilities takes place. Reviewed empirical evidence focuses mostly on people's perception of AV, on policy recommendations concerning the implementation of AV as well as on the illustration of potential effects of driverless mobilities on congestion, car ownership, parking demand and so forth. As analyzed in the respective chapter, even if societal perception towards AV has been widely researched, the same does not apply to the estimation of their potential consequences. In particular, people's perception towards AV, semi-autonomous cars, automation features of conventional cars etc. was the research object in the greatest amount of scientific evidence, found during the writing process of this project. It can be argued that the first reason for that is the importance of people's trust towards and willingness to adopt AV for the establishment of this new form of mobilities. In other words, it is acknowledged that people cannot be forced to rely on a machine for the life of their family and themselves; they have first to be persuaded that this machine is safe and second to do that because of a strong incentive. Another and maybe more important reason is that, since driverless mobilities have not been applied on a regular basis yet, examination of societal perception towards AV can produce much safer and more accurate assumptions than review of the effects of this technology (spatial, social etc.). Perception - or acceptance - surveys mostly involve a hypothetical Stated Preference (SP) questionnaire, where the respondent has to choose if he/she and under which conditions (route/cost etc.) would prefer to travel on an semi- or fully- autonomous vehicle over a conventional one. Congestion, car ownership and parking issues have also drawn noticeable attention, to the furthest possible, to the scientific society, as available data allow some preliminary simulations. Impact of AV on mobilities patterns and spatial planning as well as on place design and branding, are some of the less researched parameters of this new technology, as lack of extensive and regular applications of AV reduces the possibilities for precise estimations.

2.4.Case analysis

> *If people were exclusively trained in context-independent knowledge and rules, that is, the kind of knowledge that forms the basis of textbooks and computers, they would remain at the beginner's level in the learning process (Flyvbjerg, 2004 in Seale et al., 2004)*

Knowledge about how a phenomenon, process, project etc. is being established and proceeds (context-dependent) in accordance with context-independent rules applying in this field constitute the means of getting a holistic perspective in a broad amount of scientific issues (Flyvbjerg, 2004 in Seale et al., 2004). Examination of certain cases, where driverless mobilities are already or are about to be applied is necessary in order to gain a thorough understanding of the driving forces of its implementation as well as about the acceptance it gains by society.

Table 1: Selection criteria for case studies

Type of selection	purpose
A. Random selection	To avoid systematic biases in the sample. The sample's size is decisive for generalization.
1 Random sample	To achieve a representative sample that allows for generalization for the entire population.
2 Stratified sample	To generalize for specially selected sub-groups within the population.
B. Information-oriented selection	To maximize the utility of information from small samples and single cases. Cases are selected on the basis of expectations about their information content.
1 Extreme/deviant cases	To obtain information on unusual cases, which can be especially problematic or especially good in a more closely defined sense.
2 Maximum variation cases	To obtain information about the significance of various circumstances for case process and outcome, e.g. three to four cases that are very different on one dimension: size, form of organization, location, budget, etc.
3 Critical cases	To achieve information that permits logical deductions of the type, 'if this is (not) valid for this case, then it applies to all (no) cases'.
4 Paradigmatic cases	To develop a metaphor or establish a school for the domain that the case concerns.

Source: Flyvbjerg, 2004 in Seale et al., 2004.

Two cases were chosen for investigation; one where a driverless bus project has already taken place, Trikala, Greece and one where a driverless bus project is about to take place, Aalborg, Denmark. Selection is information-oriented and it is based on the scope of the project, which is to elaborate on "first movers" in the introduction of AV. Cases were chosen to be extreme/deviant in order to cover a relatively wide range of potential environments, where this new technology will be implemented. As unfolded below and in respective chapters Aalborg and Trikala cases are not only forerunners in terms of technological evolution but also of operational management, legal innovation and social engagement. From that point of view, they could also appear as paradigmatic, as many of the practices followed illustrate a rather intelligent way of dealing with the challenges in rolling AV out on the streets. Moreover in order for the findings of the case analysis to be more universal, cases were selected to illustrate significant variation, at least in some of their elements. Moreover cases were selected to be rather comparable in terms of kind of the vehicle, type of the service, legislation readiness (on national and international level) and kind of the field where the project takes place. In particular, studied projects involve operation of AV as PT - and not as "more easily driven" private cars -, take place in states-parties of the - quite strict in terms of autonomous driving (see chapter 4.7.) - Vienna Convention on Road Traffic and take place in urban context.

Aalborg, Denmark is one of the first cities globally where an unmanned driverless bus will perform regular service; especially in a shared path with bikes. The bus will link various parts of the area with each other and with local centres as well as with PT stops. Project will be deployed in a suburb of a city Aalborg Øst (East) from 2018 to 2022, while its duration can be further extended. Main focus points of the project are to provide better mobilities, particularly to people who might face some mobility restrictions (elderly, children etc.), and to generate social inclusion, by making local society see the bus as a piece of "communal ownership". It constitutes a part of a wider urban development and regeneration strategy, which aims at supporting spatial cohesion and enhancing urban quality of life in the area (Aalborg Municipality, 2013, Holm, 2017a,b). In Trikala, Greece it was the first time driverless technology was tested in public streets; especially in the city centre. Trikala demonstration was embedded into CityMobil2 project, used a segregated lane (with road markings and "cat's eyes" – see image 17), followed a 2,4 km route in the city centre and took place for a 6-months period (09/2015 – 02/2016) (CityMobil2, 2016a). Demonstration endeavored to illustrate technological possibilities in driverless mobilities as well as to prove the city has the competencies to apply successfully such an innovation and involve it actively into everyday practices (Raptis, 2017). Evidence for these cases stems from interviews with implementation authorities of those projects E-Trikala (Trikala Municipality Development Company), Municipality of Aalborg and Northern Jutland Transport Authority (NT) as well as from field visits, accompanied by the collection of visual fieldnotes.

2.5.Interviews

> *The research interview is an inter-view where knowledge is constructed in the inter-action between the interviewer and the interviewee (Kvale, 2007 p.1).*

Perspectives and experiences of experts or key stakeholders in a field can provide an invaluable understanding on how processes in this field are structured and evolve. Semi-structured interviews allow the interviewees to unfold their thoughts as much in detail as possible, while they establish transparency by enabling researcher to exchange their thoughts directly with them (Kvale, 2007 p. 13-14). Insight on how driverless mobilities can be realized is gained through interviews with representatives from key stakeholder institutions. This way it is intended to get knowledge of technological, political and acceptance-related difficulties the establishment of driverless mobilities will face both in Danish and Greek as well as in global context. In Denmark chosen state and regional authorities, whose object is related to driverless mobilities, are the Danish Road Directorate (Vejdirektoratet), the Danish Society of Engineers (IDA), the Federation of Danish Motorists (FDM) and the Northern Jutland Transport Authority (NT). Evidence about Greek context is obtained from E-Trikala SA (Trikala Municipality Development Company), which has elaborated a lot on this issue through the realization of driverless bus project in the city of Trikala. Interviewees are listed in table 2.

Table 2: Interviewees

Name	**Position**	**Organization/ authority**	**Aspects**	**Cases**
Andreas Egense	Head of the Sector Analysis Department	Vejdirektoratet (Danish Road Directorate)	✓	
Martin Kyed	Chief Economist, Head of the Analysis Department	IDA (Association of Danish Engineers)	✓	
Dennis Lange	Legal Advisor	FDM (Federation of Danish Motorists)	✓	
Nicolai Bernt Sørensen	Deputy Chief Executive Officer	NT (Northern Jutland Transport Authority)	✓	✓
Mette Skamris Holm	Head of the Traffic Planning and ITS Department	Aalborg Municipality	✓	✓
Odysseas Raptis	Chief Executive Officer	E-Trikala SA (Trikala Municipality Development Company)	✓	✓
Christina Karaberi	Member of the Department of Research and Communication		✓	✓
Loukas Vavitsas	Project manager		✓	✓

3. DEFINING DRIVERLESS MOBILITIES

> *A post-car system will need to be at least as effective as the current car at meeting people's economic, aesthetic, emotional, sensor and sociability requirements. This is a tall order (Dennis and Urry, 2009 p. 64).*

AV for a wide part of the population might be related with easier driving and/or with the potential to see their child or grandpa being proud of making a car move (somehow). At the same time some of them may be spending more than an hour per day to access the nearest metro station, which can be just one or two kilometers away. These include a 10-minutes walk to the bus stop, 5-10 minutes waiting time (hopefully), 10 minutes ride and maybe 5-10 minutes walking from the other bus stop to the station. Nonetheless it is not all of them who see the solution of what is described in AV. It is also highly possible that most of them would be very satisfied if there was easier parking at the station or more frequent feeder transit or higher quality pavements and bike lanes. They may think this is the best they can get.

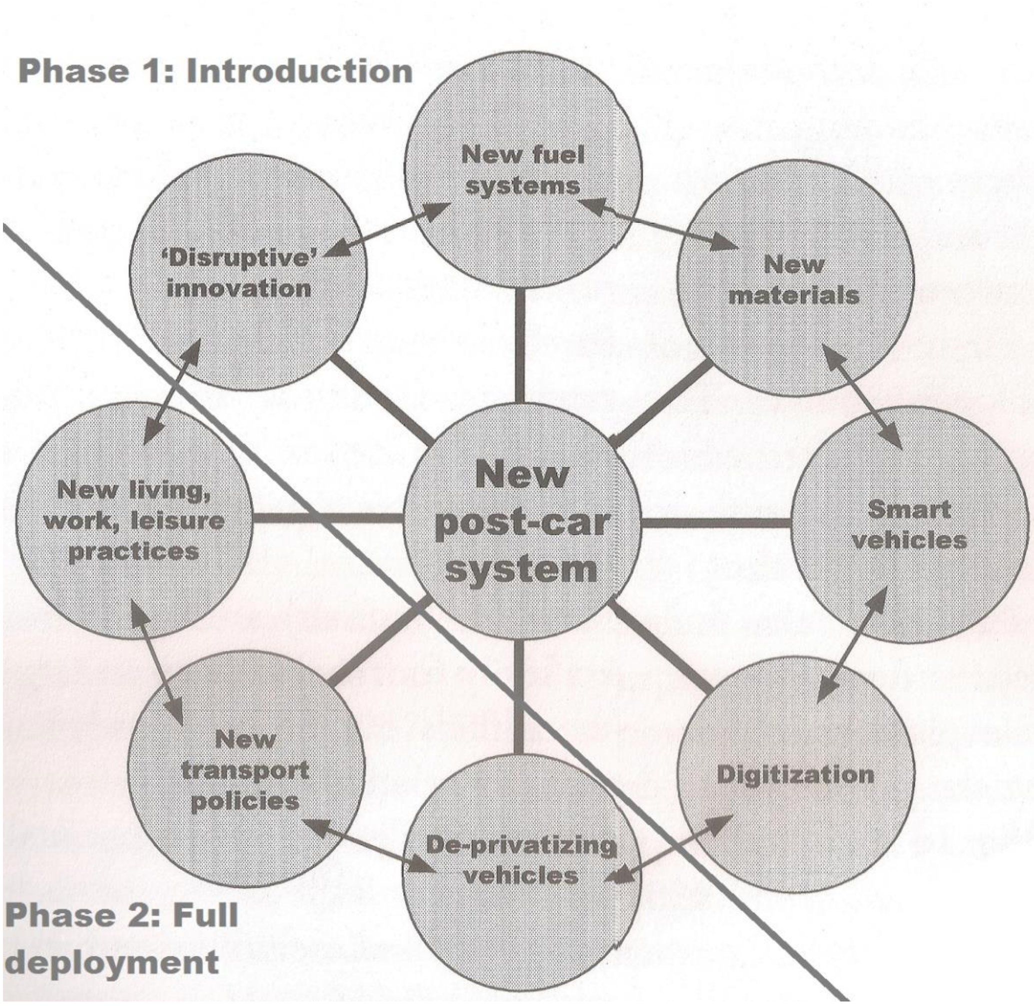
> *You never change anything by fighting the existing reality. To change something, build a new model that makes the existing model obsolete (Fuller, 1982 in Dennis and Urry, 2009 p.9).*

Mobilities are a system (Urry, 2007 p.13) and so, it can change, it can penetrate into or be penetrated by other systems (e.g. with Information Technology system) or it can evolve to a completely different one. It is preferred to use plural, as emphasis should be given in the interconnections between all kinds of physical and virtual mobility of people, goods, knowledge, experiences etc. (Jensen and Lassen, 2011). AV are not a modification of the existing mobilities system but a radically new form. AV, or the "post-car system", as Dennis and Urry (2009) address it, will be "less and individual unit and more a networked object". It will embed state of the art technology and communication features, while it will operate in a shared manner and not in a private ownership regime, which is the rule now.

> *I think over time we will more see mobility – the process of mobility – as a service and not as much as owning a car, a bike, a bus or whatever (Lange, 2017).*

The post-car system (fig. 2) consists of eight elements. These are "disruptive" innovation; new fuel systems; new materials; smart vehicles; digitization; new living, work and leisure practices; new transport policies and de-privatization of vehicles. Above mentioned features could be categorized into two groups. First group includes the first five elements and refers to the introduction phase of driverless mobilities. Then the second group, which incorporates the last three ones, depicts how the post-car system will be in its full implementation. This categorization takes point of departure from the fact that the first ones can be regarded as prerequisites for the rest. In other words, making use of disruptive innovation and the potentials offered by smart technologies in mobilities is critical in order for new transport policies to be implemented; de-privatization of mobilities to take place; and new living, work and leisure practices to be applied. Additionally, use of alternative and more environmental friendly forms of energy is a prerequisite for the successful implementation of a sustainable post-car mobilities system as well as a global target which exceeds the scopes of the field of mobilities.

Figure 2: The post-car (driverless) mobilities system



Source: Own edit on Dennis and Urry, 2009 p.64

AV will be significantly more environmental friendly than ordinary cars; while its general philosophy will be to exist and move, consuming as little energy - at least non renewable – as possible. In particular, it will use electricity or other type of renewable energy (e.g. biofuels) to move, while it will incorporate numerous energy saving technologies and practices, such as low consumption engines, lower weight of the vehicle and smoother driving. For instance, the 15-seat driverless pod Navya Arma that will be used in the Aalborg project is more than 30% lighter than a typical 15-seat Mercedes-Benz or Ford minibus (Navya, 2015, Ford website, 2017a, Mercedes-Benz website, 2017 et al.). At the same time, a large part of the Robosoft bus, used in the Trikala project is made of Aluminum, thus weighting significantly less than a typical steel-based vehicle (Institute of Communication and Computer Systems, 2015). Future car, or "cyber car" will perform decision making by itself, taking advantage of the latest artificial intelligence it will incorporate. AV will be intrinsically linked with the "Mobility as a Service" concept. According to this concept mobilities system is not just a combination of different forms of transportation (e.g. metros, buses etc) but acts as a nexus assigning each mobilities subject (agent) an integrated and individualized mobilities solution from A to B. It is built on the principle that mobilities should be conducted in the most optimized way according to the needs and personal motility of the subject ("agent") as well as to the network ("corridor") characteristics (capacity, speed etc.) at the time the trip is demanded. In other words mobilities become individual-based and demand-responsive (Dennis and Urry, 2009).

> *(…) The corridors function as a selection mechanism, which picks and chooses so that the traveler is distributed in accordance with the logic of the corridor (…) (Lassen, 2009 in Jensen and Lassen, 2011).*

AV system, along with the "Mobilities as a Service" concept, are in this project addressed as "driverless mobilities". As in the conventional version of the "Mobilities as a Service" concept, driverless mobilities will be demand-responsive, while they will be performed on the basis of achieving optimization of the system (Dennis and Urry, 2009). In particular, AV routes will be being formed "just-in-time" according to demand, while intelligent software will designate the smartest way possible to execute the trip. Route formation will take into account the wished departure and arrival times, number of passengers for each route, traffic congestion, overall suitability of infrastructure (road surface conditions, preference to high-speed bypasses and ring roads over dense urban environments etc.). In this process, mobilities "hardware" (vehicles, infrastructure etc.) and the "software" (communication between mobilities agents, vehicles, infrastructure etc.) will be of equal importance, as mobilities will be a more “smart” activity than today (see figure 2) (Dennis and Urry, 2009, Jensen and Lassen, 2011).

Taking the above analysis as departure point it is evident that driverless mobilities will actually be much more than a solution for the last mile problem, while their very nature may even put on risk the notion of PT itself. Yet, last mile problem will just be one of the first and most important challenges driverless mobilities will have to accomplish. Next chapters constitute an effort to study when and to which extent this new form of mobilities will finally be deployed and how it will eventually shape future mobilities. Moreover it will be examined if selected cases adopt the paradigm depicted in this section and which of its elements are embedded into them.

4. HISTORY AND DEVELOPMENT OF DRIVERLESS MOBILITIES

In the previous chapter it has been endeavored to gain a thorough insight on the concept of driverless mobilities, so that the elements of this form of mobility are clearly understood and defined. This chapter begins with a description of the features of each kind of AV, or the "levels of Automation", formed by the Society of Automotive Engineers (SAE). Then it continues with a historical retrospection of driverless technology from its birth to current times; while the aspects of the transition phase towards the fully driverless era are illustrated. Afterwards a critical review of the benefits of and the concerns regarding this new form of mobilities takes place; followed by a discussion on if and how this technology is – and will be – accepted by society. Next, an overview of existing legislative framework on AV takes place along with a discussion on future law or convention amendment proposals. Last but not least the chapter features an investigation of the ethical issues arising by the particularities of this form of mobilities and by the removal of the human factor in the driving activity.

4.1.SAE levels of automation

AV do not operate all the same way or have the same possibilities. Car automation varies from the rather simple cruise control, that keeps vehicle's speed in a certain level and is already widely used, to the completely driverless car where user has just to enter his/her destination and the rest lie on the vehicle. These situations are illustrated as 'levels of automation' and are categorized by the SAE as illustrated below. There are 6 levels, varying from zero automation, where driver has to perform the entire driving task to five, where vehicles take full control and perform all decisions concerning their movement. In levels 0, 1 and 2 driver is predominantly performing the driving task, while in the following three the role of the driver is being increasingly adopted by the car itself.

Figure 3: SAE levels of automation

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Source: SAE, 2017

4.2.From the "Magic Motorways" to the driverless pods

Driverless mobilities have been largely developed over the last years in the form of vehicles which run in their own guideway, either on rails or on rubber wheels (Alessandrini et al., 2014). Such vehicles are used in Personal Rapid Transit (PRT) systems, where transportation is usually point-to-point in a specific route, area or facility, or in many contemporary railway networks, if no points of friction between road traffic and the railway line exist (Copenhagen, Paris, London etc.) (Copenhagen Metro Company website, 2017). Implementation of this new form of mobilities in mixed traffic is still at an immature stage. Currently available technology reaches level 2, as in many cars steering and acceleration/deceleration can be done under certain circumstances without input from the driver (Kyed, 2017a et al.). Level 4 and 5 vehicles, like the ones of the cases examined in this project, have also hit the roads in the last few years but mostly in trials, at low speeds (less than 20-30 km/h) and usually with somebody present at the vehicle to take over control in case of emergency.

4.2.1. PRT

PRT and Group Rapid Transit (GRT) systems offer Point-to-Point transfer, are driverless, use rubber-wheeled vehicles (pods) and run on their own guideways. Each pod typically has 3 to 6 seats, while its speed is near 40-45 km/h (2getthere website, 2017, Ultra Global PRT website, 2017). First PRT system is the Morgantown People Mover (MPM), which was launched in 1975 in Morgantown, West Virginia, United States (US) and connects neighborhoods of the city with West Virginia University (WVU) and the local hospital, carrying daily 15.000 passengers during the school year (WVU website, 2017). Next applications of PRT/GRT systems took long to appear. One of the efforts to realize PRT later was the French experiment “Aramis” in the 80’s, which nevertheless was unsuccessful. This could be attributed to the fact that it was less “smart” than it should be for its role (Dennis and Urry, 2009). For instance, connection of platooning vehicles, which was non-material (!) and was assured by visual and ultrasonic sensors was difficult when it was raining, thus ending up many times to collisions (Anderson, 1996). It could be assumed that such issues would not exist today, as similar sensors are far more intelligent; thus connecting the vehicles with considerably greater accuracy. In general it can be supported that knowledge coming “from the cloud” is critical for PRT systems to offer the best of their possibilities, e.g. to optimize routing, to be aware of congested corridors, to forecase demand etc.. It should also be taken into consideration that when PRT was invented, automobility had not been popular for long (it had been almost two to three decades). Hence society might not be willing to renounce attributes of the latter, like privacy or the freedom to make 100% the choices available in their trip without having “experienced” it sufficiently over time. PRT was again realized 22 years after the MPM, in 1997, in Amsterdam Schiphol airport (ceased in 2004), Rivium Business Park, Rotterdam; Masdar City, Abu Dhabi; London Heathrow Airport, and Suncheon, Korea in 1997, 1999, 2010, 2011 and 2014 respectively (2getthere website, 2017, Ultra Global PRT website, 2017 et al.).

Image 1: Morgantown People Mover

Source: Keyword Suggest Encyclopedia website, 2016.

Image 2: Masdar City PRT

Source: PRT Consulting website, 2015.

PRT could be regarded as the predecessor of AV, but with a considerable drawback; it needs its own guideways. MPM's cost reached the noticeable sum of 319 million $ in 2004 dollars, for a 8,7 miles (14 km.) network, or 22 million dollars per km.. This is greatly owned to political pressure for quick construction, risk of new technology and to the fact it was not a mass-construction project, thus not being able to get benefit of extensive network economies (Raney and Young, 2004). Creating a modern PRT system is not a low-price solution either, as it can cost between 7 and 15 million $ per km, without tunneling or other extra features (Raney and Young, 2004, Ultra Global PRT website, 2017). That could be the main reason for which, even if PRT first appeared in 1975, it took 22 years for its second implementation and 11 more years to come seriously to the forefront (CityLab website, 2014), while even so, very few projects have been realized since then. Future will need AV to run mostly on conventional infrastructure, so that deployment of fully driverless mobilities is not prohibitively expensive.

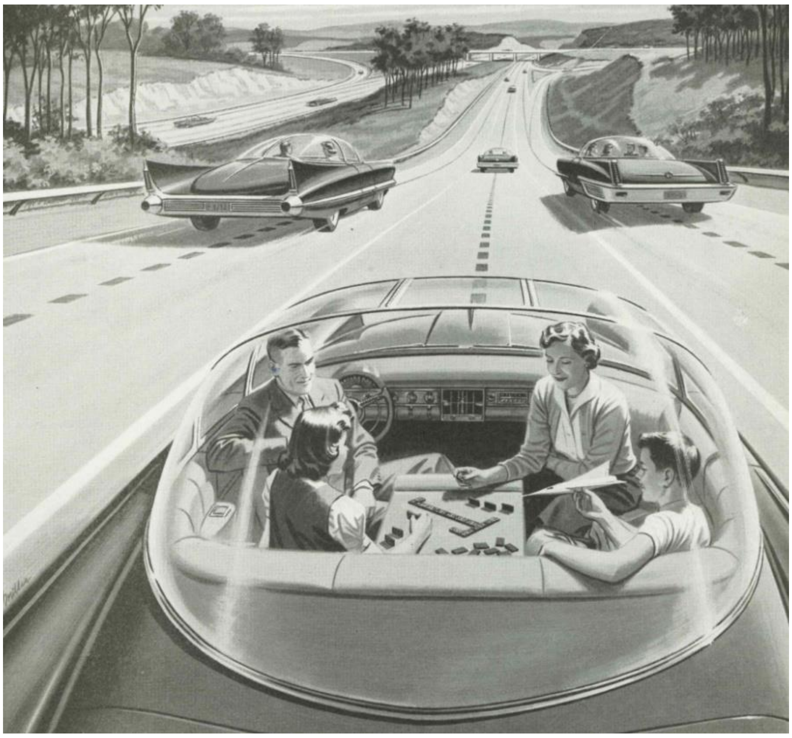
4.2.2. AV

Car automation is not at all a recently made progress, as its first envisioning dates back to the externally controlled *phantom cars* of the 1920's (theatlantic.com , 2016, engineering.com, 2016). A primitive version of the AV concept was illustrated at the 1939 New York World's Fair, where designer Norman Bel Geddes incorporated them in his exhibit *Futurama* (Geddes, 1940). *Futurama* was a visionary concept, which targeted at the facilitation of people and goods movement across the country, enabled by the automated "Magic Motorways" and suburb-based spatial development (Geddes, 1940). Magic Motorways featured trench-like lanes, accompanied by electromagnetic trails, in order for the vehicles to keep their lanes, while vehicles were embedding railway signaling systems and electronic speed controls (Geddes, 1940). Serious research on driverless technology began at the 60's (Beiker, 2012) and first projects involving truly self-driving vehicles were conducted for the US Defense Advanced Research Projects Agency (DARPA) by Carnegie Mellon University's (CMU) Navlab and University of Michigan in 1984, as well as by a partnership of Mercedes-Benz and Bundeswehr University Munich in 1987 (Chittilla and Sun, 2017). First coast-to-coast driverless car trip – "No Hands Across America" - was also implemented by CMU's Navlab in 1995, where 98,2% of 2,849 miles from Pittsburgh to San Diego were completed autonomously at an average speed of 102,3 km/h (CMU's website, 2017).

Image 3: The “Magic Motorways”

Source:http://image.superstreetonline.com/f/27065978%20w%20h%20q80%20re0%20cr1/epcp-1004-02-hp+visionary-norman-bel-geddes+superhighway.jpg, 2017.

Image 4: The vision of autonomous cars in 1950’s



Source: Computer History Museum website, 2014.

Image 5: Google AV Waymo

Source: Autocar United Kingdom (UK) website, 2016.

> *If you look at the enormous investments of car manufacturers and software companies, it seems that a lot of people out there can see substantial benefits for consumers. (...) So the reason they are spending that much (...) is that they may think this is the only way that they can have a future (Kyed, 2017a).*

In the recent years level 4 or 5 AV tests have been implemented in Berlin, Germany; Paris and La Rochelle France; Helsinki, Finland; Milton Keynes, UK; Perth, Australia; Singapore; Pittsburgh and Las Vegas, US; Lausanne, Switzerland; Wagenigen, Netherlands (The Telegraph website, 2016, Digital Trends website, 2017 et al.). At the same time a wide range of areas like Vesthimmerland Municipality and Copenhagen (Nordhavn), Denmark; Dubai, United Arab Emirates (UAE); Hamburg, Germany are planning to implement driverless mobilities for a vast number of uses (e.g. municipal services and short-distance transit feeders) in the near future (Vesthimmerland Municipality website, 2017, The Local (Germany) website, 2016, Teknik Nyt website, 2017 et al.). AV applications are so far usually being conducted with “pods” (see images 6 and 7), whose capacity varies from 6 to 12 passengers and their speed is between 12 and 30 km/h (Deutsche Bahn website, 2017, CityMobil2, 2016a, Madigan et al., 2016 et al.).

Image 6: Driverless pod in Berlin

Source: Inside-handy.de, 2016.

Image 7: Driverless pod in Berlin - interior

Source: Die Welt website, 2016

Diffusion of autonomous technology in the market has already taken place through the enrichment of conventional cars with Advanced Driving Assistance Systems (ADAS). Purpose of those kinds of equipment is to execute some parts of the driving task, supporting the decision-making process of the driver, as well as to prevent human fault. ADAS include among others the Adaptive Cruise Control (ACC) (car moves at fixed speed, which has been set by the driver), Lane Keeping Assist (LKA), collision avoidance systems, automated parking equipment and blind spot detection. These driver's assistance means have gained growing popularity since their inauguration two or more decades ago (Toyota Global website, 2012) and they are now available even at medium-sized cars (Lu et al., 2016, Ford website, 2017b, Carscoops.com, 2016). Moreover, another wide-scale project with AV is Google Waymo, which was introduced in the US in 2009 and has already accomplished 3 million self-driven miles (Waymo website, 2017). Another milestone in the establishment of driverless mobilities was the introduction of Tesla's autopilot in October, 2015 (National Highway Traffic Safety Administration of the US, 2017). This equipment, as stated in National Highway Traffic Safety Administration of the US (NHTSA) (2017) allows the car to drive at a fixed speed in an standardized environment, such as a motorway almost without driver's input (NHTSA, 2017, Automotive News website, 2015).

> *The Autopilot system is an Advanced Driver Assistance System (ADAS), which controls vehicle speed and path by automated control of braking, steering and torque to the drive motors (NHTSA, 2017).*

Autopilot has two components Traffic-Aware Cruise Control (TACC) and Autosteer. TACC keeps the car's speed at a fixed rate, chosen by the driver, like the conventional cruise control, but has also sensors to identify proceeding and following cars. This is in order to make driving on a motorway more convenient, by reducing the need for the driver to turn the software off every time a slower vehicle is in front of the car. Autosteer goes one step ahead and identifies cars and other moving objects in the adjacent lanes, so that the car can change lanes (e.g. to overtake) without input from the driver. Above mentioned equipment is still not fully developed; this is why so it can work only under standarized conditions, such as in motorways, where it can have better knowledge of the driving environment, than e.g. in cities. Furthermore, it is made clear that driver should at any time have their hands on the steering wheel, pay attention on the driving task and be ready to takeover control, as well as that he/she is equally responsible for car's movement as if it was a fully manual car (NHTSA, 2017). Along with the inauguration of Tesla Autopilot, sharply increased progress in that field by many other companies like Mercedes-Benz, BMW and so forth was noticed (Car and Driver website, 2016).

4.3.Towards a driverless future: Aspects of the transition phase

> *I think in the transition phase we might see an increase in accidents (Holm, 2017a).*

> *I think something like autonomous driving will only be possible in an environment where all traffic is autonomous (Kyed, 2017a).*

Introduction of level 4 or 5 cars in the market is usually placed around 2020 (Danish Road Directorate website, 2017a, Solis, 2017 et al.) while entire mobilities are believed to become driverless between 2040 and 2065 (Lange, 2017, Bansal and Kockelman, 2017, Danish Road Directorate website, 2017a). Even if driverless technology can work safely and reliably in predefined routes and a wide range of environments, it cannot be supported it is equally ready to perform driving task under all conditions (Holm, 2017a, Lange, 2017 et al.). Time needed for switching to fully driverless mobilities depends largely on readiness of technology to undertake entire driving task, on legislation, on social acceptance, on expected lifespan of currently sold cars and of course on perceived comparative advantages over conventional vehicles (Krueger et al., 2016, Collingwood, 2017 et al., Lange, 2017).

> *I think you'll never get the full benefits of autonomous vehicles as long as there are ordinary vehicles out there.(…) So there are some of these benefits from AV that will not be seen until the last manual car is over (Kyed, 2017a).*

Taking as point of departure the analysis from previous sections it could be argued that implementation of driverless mobilities will not happen far late from now due to their considerable economic, environmental and safety benefits. However, transition phase will probably not be seamless for two reasons. First comes that coexistence of manual cars and AV will cause major traffic problems and probably more accidents (Holm, 2017a, Loon and Martens, 2015 et al.). due to the incompatibility among practices of ordinary and autonomous vehicles. In specific, modus operandi of autonomous vehicles will be optimization-based, manual cars will move in a more "suboptimal" way, while actions of both may be largely unpredictable by the other party (Loon and Martens, 2015, Goodall, 2014). This means that in a foreseen accident for instance, the way a human driver will act to prevent it may be the opposite than the AV will choose (e.g. both cars turn to the same direction). That "mismatch" may be the cause of a collision, which would have been avoided in case both cars were either manual or AV. Egense (2017) described a truck-platooning test that took place in Denmark in May, 2016, which, in spite of its success, highlighted some weaknesses of the coexistence phase:

> *Trucks were driving at 80 km/h (...) and another truck was overtaking them at 81 km/h. It was a situation where this truck did not have to overtake one truck but three, meaning all traffic was stuck behind the trucks in both lanes for let's say for a minute. This is not good utilization of capacity. That is an increase in congestion (Egense, 2017).*

Alleviating threats of coexistence of conventional and autonomous vehicles could be solved by limiting their friction as much as possible. For instance, there could be a phase when using fully autonomous mode is allowed only in the motorways; while when entering an urban area all vehicles should be manually driven (Kyed, 2017a, Holm, 2017a).

> *How will the politicians make it?(...) Will at some point say you can't go on a highway if you drive a manual car? We don't know. It's possible when we reach maybe 95% penetration of AV that it will be optimal to make it (Kyed, 2017a).*

Second matter of transition phase is the huge safety concerns that arise from the operation of semi-autonomous vehicles. In these vehicles, it is expected that drivers monitor driving task all the time and are ready to takeover control within a specific time period whenever needed. However it could be argued that expecting people to takeover control in short time at the moment they are – reasonably, in a sense – extracted from the driving task is rather ambitious, if not utopic (Lange, 2017, Kyed, 2017a). At the same time overreliance on semi-automation may seriously affect perceived seriousness of driving, thus making people with insufficient driving education, experience or ability (drunk/impaired etc.) to drive beyond their personal boundaries. Therefore, it should be clearly stated and widely communicated that driving a semi-autonomous car – or a car where driving task requires any point of human intervention - brings same responsibilities and restrictions with driving a fully manual one. As a consequence of all the above it could be supposed that safety and operational threats of mixed traffic will by nature prevent this situation from existing for a long period of time. Therefore is can be supposed that mobilities will become fully driverless shortly after the introduction of level five vehicles, namely by 2035-2040, or even earlier (Holm, 2017a, Pillath, 2016, European Road Transport Research Advisory Council, 2015)

4.4.Benefits

Driverless technology can bring unforeseen traffic safety gains, significant environmental benefits, important cost savings, enhanced mobility for currently unable or unwilling to drive (elderly, children etc.), considerable increase in travelling speed and road network efficiency as well as possibility for better travel time utilization.

4.4.1. Road safety

Around 90% of all road accidents are due to human error (Kyed, 2017a,b et al.), therefore extracting human factor from the equation may bring a respective decrease in the number of accidents. Safety gains have already occurred just from the embodiment of ADAS into conventional vehicles. In specific, NHTSA (2017) shows that after Tesla embedded Autosteer function (see chapter 4.2.2.) in its Models S and X, crash rates of those models fell by 40%. This could be considered as a very positive indication of the potential of AV to make roads substantially safer:

> *Actually we are not at level 3 yet and it's very very promising if, already at level 2, accidents have decreased by 40%; That's huge (Kyed, 2017a).*

4.4.2. Economy

Apart from human losses represented by those rates, reduction in accidents would also lead to notable economic benefits (Manyika et al., 2013 et al.). In Denmark 2778 traffic accidents with injuries happen annually, having a cost of 5,4 mil. Danish Krones (DKK) (726.000 euros) each (Kyed, 2017b). Kyed (2017b) notices that even if reduction of traffic accidents is not 90% but just 67% instead, economic savings for Denmark could reach 10 billion DKK (1,3 billion euros), as much as the cost of a 18 km bridge which links two major parts of Denmark, Jutland and Sjaelland, Great Belt. In addition to that, travel time cost is considered to be 11,5% lower in trips made with level 3 AV than in the ones made with conventional cars (Kyed, 2017b). For 715 million driving hours, which is the annual total amount of driving hours in Denmark, economic benefits could reach up to 9,9 billion Danish Krones, doubling the total gains of the country from AV (Kyed, 2017b). Respectively, in Germany AV will generate wealth of 8,8 billion euros for the country's economy, while 130.000 new workplaces will be added to national labour market until 2025 (Lutz, 2016). Moreover, as fully automated vehicles will be electric (Fagnant and Kockelman, 2015 et al.), important energy, emissions and cost reductions can also be achieved. Fagnant and Kockelman (2015) estimate positive economic impact of AV to 196 – 442 billion dollars in US, coming mainly (54%) from reduction in accidents and 31% from alleviation of traffic congestion. On a global scale Manyika et al. (2013) suggest savings of 1,9 trillion dollars, deriving just from travel time utilization, applying even on an AV penetration rate of just 5-20% (higher rates apply to developed countries, while lower to developing ones). AV will also reduce demand for parking spaces by up to 90%, thus allowing better and more people-oriented utilization of urban space, such as for parks or other recreation facilities (Zhang et al., 2015, Lange, 2017)

4.4.3. Filling the gaps of Public Transport

AV may also perform point-to-point or fixed route shuttle services inside neighborhoods/campuses etc.; or as feeders to the main PT system – either regular or Demand-Responsive Transit (DRT) - thus decreasing usefulness of private car, as well as willingness to own it (Sørensen, 2017, Raptis, 2017, Cervero et al., 2004, et al.). They can also operate in areas with low income/low car ownership levels in order to alleviate mobility constraints of local inhabitants, like in Aalborg East, as analyzed later.

> *We can make it (driverless bus in Astrupstien) so people can use an app or something and then have their vehicle at their door within 5 – 10 minutes or something like that, at least in a small system like this (Holm, 2017a).*

AV may play a dominant role in supplementing and therefore supporting PT with better feeder or DRT services, as the lack of sufficient feeders, or the "last mile problem", is one of the main challenges PT faces (Cervero et al., 2004, Raptis, 2017 et al.). It should be noticed that efforts to provide alternatives for the last mile problem using conventional (not driverless) modes of transportation have already taken place, but in most cases unsuccessfully. In particular, high operational costs or insufficient scale economies usually prevented them from being economically sustainable, even if they met demand requirements (e.g. Kutsuplus service in Helsinki) (Sulopuistto, 2016, Ryley et al., 2014). DRT can also operate for longer routes, for instance in areas where demand is not high enough to maintain an ordinary fixed bus line. An example of that is the rural area of Northern Jutland region in Denmark. In this area it was decided around 20 years ago to shut down rural bus routes due to weak ridership and very low efficiency (Sørensen, 2017). Instead, NT replaced lost bus routes with “flextur” DRT service, which is conducted by taxis and minibuses. System works through NT’s app “Rejseplanen” where passenger chooses their departure and destination points and the app finds the optimum way of making the trip. In case starting and/or ending point are in a rural area which is not served by ordinary PT Rejseplanen includes use of “flextur” service and calculates the price for the entire journey. Then feeder means (taxi or minibus) is coordinated with the timetables of the arterial bus/train line passenger uses so that waiting time will not exceed 15 minutes and of course passenger will not arrive at the stop later than the main bus/train departs. NT has contracts with around a thousand taxis and minibuses in the entire region, while on annual basis 100.000 trips are being made. System proved to satisfy demand for rural mobilities in Northern Jutland in a far more effective way than the previous one, providing both reduction of waiting time for the passengers and significant cost savings for the company. However, economic viability of the system is still far from being the reality:

> *You can take this trip (from a rural area to the nearest PT hub) for 22 DKK, but our cost for this trip is about I guess 120 DKK. But exactly the money weput in this route before(when there was regular bus service in those routes) were even more than that (Sørensen, 2017).*

Role of AV in increasing sustainability of DRT system can be decisive:

> *.. it (AV) will give us some advantages in our ordinary public transport system. (…) If we can use AV as feeding to the main network (arterial bus and train lines) then it would be a very good business case for us we think (Sørensen, 2017).*

Conversion of this system with an AV-empowered one may not take considerable time and economic resources, as its basis is similar to the conventional one:

> *We have the IT system that can make the global coordination. So actually we only miss the (driverless) cars…(Sørensen, 2017)*

Labour costs count for 50% - 75% of total public transportation cost (Sørensen, 2017), thus constituting a largely preventive factor in achieving sustainability of DRT systems and maybe of general PT as well. Flextrafik cars (taxis/minibuses) charge NT 300-400 DKK per hour, while approximately 210 DKK out of them (up to 2/3 of the price) is the cost of the driver

(Sørensen, 2017). Hence potential reduction of transportation cost to that extent brought by unmanned operation can even redefine economics of this field, opening up a vast array of new possibilities (Sørensen, 2017, Holm, 2017). These involve higher frequencies, increased capacity, enhanced off peak services and better coverage of sparsely populated areas (Alessandrini et al., 2014, et al.). Moreover, lack of drivers' availability issues will enable "just in time" rou, thus allowing far better allocation of public transport system's resources (Alessandrini et al., 2014 et al.). However, it will take some more time for AV to achieve considerable penetration rate in the public transport system. This is because of a wide range of reasons beginning from legal barriers, technological readiness, social acceptance and so forth, as analyzed in the "transition phase "section.

> *AV are not a part of our strategy (until 2019). They have to be a part of our strategy somehow, but we don't know exactly when the right time is to involve us deeply in this kind of politics (Sørensen, 2017).*

Cost of this technology can also be considered as one of the constraints in its launching on public streets. A common 15-passenger electric driverless pod, like the one that will be used in Aalborg East trial costs around 1,7 mil. DKK (approx. 250.000 euros) (The Telegraph website, 2016). That may be pricey for a low-capacity and low-speed – therefore low-range – means of transportation. On top of that, electricity also constitutes a non-negligible expense, especially in countries where taxation for electric power is tough, like Denmark (Holm, 2017a). However, a very strong advantage of this technology is low manufacturing lead times (Kyed, 2017a). In addition to that, data needed for the vehicle to move (mapping etc.) will not have a huge cost (Holm, 2017a).

> *As our mobile phones and other technologies that eventually became cheap, I think it will be the same kind of development in this type of vehicle (Holm, 2017a).*

4.4.4. Traffic

Shared mobilities will lower amount of car traffic and vehicles, thus reducing congestion and improving quality of urban environment (Egense, 2017, Fagnant and Kockelman, 2015 et al.). Relative studies depict an up to 93% shrinking in car fleet, as one fully autonomous vehicle can replace 8 to 14 conventional cars (Alonso-Mora et al., 2016, Rigole, 2014 et al.). In addition to that, since automated vehicles will embed V2V (Vehicle to Vehicle) and V2I (Vehicle to Infrastructure) - or just V2X (Vehicle to everything) – communication (Fagnant and Kockelman, 2015 et al.), use of infrastructure will be optimized in many ways. First, AV will move more accurately than human drivers, therefore they will be able to keep lower longitude and latitude safety distances as well as they will be to move in platoons (Wietholt and Harding, 2016, Egense, 2017. Lioris et al., 2017 et al.). According to estimates, this may induce 30% increase in the capacity of motorways (Danish Road Directorate website, 2017b, Lange, 2017). Second, distribution of road space and traffic lanes will vary according to demand. For instance, in a six lanes motorway that connects suburbs and city centre, centre-bound flow can possible acquire four out of them during morning inward peak, while the opposite will happen in afternoon outward peak. Additional capacity benefits could occur by converting emergency lane from permanent to temporary and use it as emergency lane again when needed (Egense, 2017). This would be feasible by V2V and V2I, which will instantly inform the entire amount of approaching vehicles when an accident happens to live the lane unoccupied. Third, introduction of this technology will probably lead to an increase in the speed limit in many cases, first due to the missing out of human fault and second due to the enhanced knowledge of the car about the infrastructure and the rest of the traffic. For instance, in intersections, since the car will be aware of the amount and the speed of crossing vehicles, it will be able either to accelerate in case available time is sufficient to do so, or to slow down earlier in order to make trip smoother and save energy. Kyed (2017a), taking into account the expected reduction in road accidents (see chapter 4.4.1.), considers the increase of speed limit as highly expected:

> *I would say it would be natural that if we see a decrease in accidents we should actually be allowed to drive faster (Kyed, 2017a).*

On top of the above, as new “smart” traffic lights will be aware of the vehicles approaching, their operation can be converted from a time – based one to a demand-based, thus bringing considerable capacity benefits up to 80%; hence notable reduction of travel time (Chen et al., 2017).

4.4.5. AV as “living spaces”

AV will not need driver’s input, while at the same time they will embed state of the art smart technologies. So it will be possible to enhance usefulness and productivity of travel time by enabling a vast number of possibilities e.g. leisure, communication or distance working (Kyed, 2017a, Lange, 2017). Converting the car from a private driving machine to a “selfmoving" space will allow vehicles to be designed as "living spaces" and suggest a new type of aesthetic and quality. In particular, user will not focus on the system-related features (e.g. maintenance intervals/costs) but on how smooth and pleasant the passenger experience is (Web urbanist website, 2015 et al.).

A synopsis of all the above could be that automation is expected to increase mobility, improve road safety and facilitate sustainability. Yet, fully driverless future comes along with some non-negligible concerns on how AV will affect traffic, environment, space and so on. A great proportion of them will be discussed in the following section, while examination of perception-related, legal and ethical issues will take place in individual sections afterwards.

4.5.Concerns

Full replacement of ordinary vehicles with AV comes with many questions over traffic, economy, safety, security and liability issues. First, none of the previously mentioned benefits will occur if AV will be owned privately and in the same regime as today. This is because making the entire population able to move themselves in their own car will put unforeseen pressures on road network and bring dramatic increase in energy consumption, carbon emissions and parking demand (Sørensen, 2017 et al.). In specific, in a scenario where all vehicles are privately owned, in the same regime as today, Danish Road Directorate (website – 2017b) predicts up to 14% traffic increase on average in all parts of road network, reaching 20% in Motorway traffic. Moreover, in US context, Harper et al. (2016) conclude that access to personal vehicles to those who do not have a driving license and the elderly will entail 14% increase in Vehicle Miles Travelled (VMT) of residents aged 19 years or older. Second, it is understandable that a part of the society has an uncertainty on if computers can perform entire driving task, at least in the near future (Raptis, 2017, Lange, 2017). Third, security issues also bring significant hesitations among society. In specific, even if AV will feature state of the art security software and protocols, fears over software malfunction, unauthorized access to personal data, hacking or cyber attack still exist (Kyriakidis et al., 2015, Collingwood, 2017 et al.). Fourth responsibility and liability matters have to be precisely defined, along with each stage of technological progress in driving automation (Collingwood, 2017). In particular, in order for people to trust and make use of any available automation feature, two main conditions shall be fulfilled. First they should be sure that offered automation features are sufficiently tested and reliable; and second they should know who is responsible in case of equipment malfunction or failure. Last but not least, level five mobility will inevitably move the art of driving out of public streets (Lange, 2017 et al.). Therefore transition to the age of full automation in mobilities should be accompanied by allowing this form of art another form of expression, e.g. motorsports (Holm, 2017a). On top of the above, car ownership for many people constitutes a means of social recognition (Lange, 2017). Hence, it should be examined which elements of AV will counterpose branding elements of ordinary cars. At the same time, even if travel time utilization may allow numerous new possibilities for AV users, it may have a drawback too:

> *When you are sitting in your car and your steering wheel you are paying attention to traffic but you don't have to worry about all the other things in your life. That will be different in an autonomous car. It may mean that instead of now when you are typically working eight hours a day, you will be suddenly working ten hours or twelve hours. Therefore that might be a benefit for the boss but not necessarily for the person in the car (Lange, 2017).*

4.6. Societal perception of AV

Perceptions of people towards AV are positive to a great extent (Christie et al., 2017, Hohenberger et al., 2016, Lange, 2017), yet further relevant research should take place (Bazilinskyy et al., 2015, Krueger et al., 2015). Uncertainty arises due to many factors, beginning from the lack of applications of the new technology; especially wide-scale ones (Yap et al., 2016). Most acceptance surveys take either point of departure from how people imagine driverless mobilities or at best follow up a short-term AV trial (Kyriakidis et al., 2015, Christie et al., 2016, Piao et al., 2016 et al.). Moreover, in many public surveys it happens that participants have not experienced AV or might be misinformed to an extent on how this technology works; thus expressing some kind of hesitations or reluctance (Piao et al., 2016). Indeed, greater knowledge and/or richer experience on automation in mobility induce better perceptions towards it (Alessandrini et al., 2015b, König and Neumayr, 2017 et al.).Existing evidence suggests younger people and men appear as more positive towards AV, in opposition to women and elderly who tend to show less trust to driverless technology (Hohenberger et al., 2016, Kyriakidis et al., 2015, Haboucha et al., 2017). Urban residents seem to be more positive towards driverless mobilities (Kyriakidis et al., 2015, König and Neumayr, 2017). A reason for that can be the greater visibility of privately owned automobility's drawbacks (gas emissions, occupation of public spaces etc.) and the limited freedom of the car (congestion, restrictions of access e.g. to the city centre due to high parking cost or congestion pricing, etc.) in cities. For instance, Lu et al., (2017) indicate that in Atlanta more people would choose to live in Transit-Oriented Development (TOD) districts, combined with AV rather than in traditional car-dependent suburbs. Another survey (Payre et al., 2014) among French drivers shows they would be more willing to switch to automated driving in motorways, congested traffic and for the parking task. Preference upon driverless mobilities has been greatly linked with personal locus of control (Payre et al., 2014, Choi and Ji, 2015).

> *Locus of control is defined as a personality trait that echoes the extent to which a person believes he or she can control events that affect him/her (Payre et al., 2014).*

In particular, it is claimed that people who rely mostly on themselves for controlling their environment, namely have *internal locus of control* will be less positive to AV as they will "distract" a part of this control from them. Contrariwise, people with *external locus of control* who rely more on exogenous factors for controlling their environment are more positive into assigning their movement-related decision making to a machine (Payre et al., 2014, Rudin-Brown and Noy, 2002). It may be important, at least during the transition phase that extensive information on driving patterns AV will be given to users in order to enhance transparency and create trust between them and machine (Choi and Ji, 2015). Vital concern for a wide part of the population for the era of full automation is also the potential lack of freedom to make options for their trip (Collingwood, 2017). On that basis, providing detailed information about the trip (route, stops, reasons to select specific route etc.) and the possibility for route amendments/extra stops etc. could also be useful to support the sense of freedom to users. In addition to that, as trust is a determinant of AV adoption (Choi and Ji, 2015) education about the benefits of AV should take place (Hohenberger et al., 2016, Bansal and Kockelman, 2017), also addressing society's concerns over AV's operation, safety and security issues. Another personality trait, namely sensation seeking is considered to influence willingness to adopt AV as well (Payre et al., 2014, Rudin-Brown and Noy, 2002), yet the opposite is also believed (Choi and Ji, 2015). Human-like appearance of technological equipment has also been associated with increased familiarity of people with electronic devices (Lee et al., 2015). In spite of all the above, research shows that even if personality traits largely shape perceptions towards technological innovations like AV, practical benefits are the “playmaker” in gaining society’s acceptance on driverless mobilities (Krueger et al., 2016, Piao et al., 2016). To state this in a different manner, people will adopt driverless mobilities if perceived benefits, such as lower mobility cost, increased frequency or extended operating hours overcome the “costs”, such as the lack of social presence onboard or the lower speeds (at the first stage of their implementation).

4.7.Legislation – liability issues

Any vehicle shall comply with specific safety and operational regulations in order to be allowed to get in traffic. AV will eventually have no drivers and their operation will be entirely based on technology. So legal framework governing AV shall regulate both movement-related issues (e.g. speed, traffic planning, liability in case of accident) and technology-oriented matters. (e.g. system security, hacking protection). Lack of full legal recognition is for many the main reason AV have not been widely introduced so far (Alessandrini et al., 2014). However waiting is preferred from acting ahead of time for most policy makers, as it is of critical importance for this innovation not to run on the streets before legal and liability issues have been clearly defined (Raptis, 2017, Kyed, 2017a et al.). On a global scale, structural laws and principles about road traffic – and hence about AV - are formed by two international conventions Vienna Convention on Road Traffic (VCRT) and Geneva Convention on Road Traffic (GCRT), depending on the country. Since these conventions are quite old, it makes sense they do not make any provision for driverless technology. However, a wide range of countries around the world, including Denmark and Greece in this project, have applied laws that allow embodiment of AV in mixed traffic under certain conditions. As it would be important to discriminate the relatively more changeable national legislations from the less flexible international conventions, this categorization also applies to the examination of legislation regarding AV in this chapter.

4.7.1. International conventions and law

VCRT is the main international legal text that AV’s operation has to abide by. VCRT is ratified by 75 countries, mostly in Europe and Asia as well as by some in Africa, Central and South America (United Nations Economic Commission for Europe, 2017, United Nations Treaty Collection, 1968). Countries that are not parties of this VCRT, like US and Australia may abide by GCRT of 1949 (United Nations Treaty Collection, 1949). GCRT is believed to be more “tolerant” in driverless technologies, which makes technology diffusion easier in States parties of this Convention e.g. United States (Pillath, 2016). VCRT addresses driver’s role as following (article 8, §1 and §5):

> *(1) Every moving vehicles or combination of vehicles shall have a driver.*
>
> *(5) Every driver shall at all times be able to control his vehicle or to guide his animals.*

As set above, driver’s role is legally dominant for any driving activity in states parties of the convention. However, update of VCRT, which sets up the foundation for legal recognition of AV, came into force in 23 March, 2016:

> *As of that date, automated driving technologies transferring tasks to the vehicle will be explicitly allowed in traffic, provided that these technologies are in conformity with the United Nations vehicle regulations or can be overridden or switched off by the driver (United Nations Economic Commission for Europe website, 2016).*

Another update, regarding adoption of automated steering technologies, is under discussion by United Nations Economic Commission for Europe (UNECE) and is expected to become a component of VCRT in the next period of time (UNECE website, 2016). Both amendments constitute a sort of legal recognition of semi-autonomous vehicles; yet they preserve the leading role of the driver in any driving-related decision making. Hence, driver, either present at the vehicle or monitoring it from distance, is liable for any accident or incident might happen (CityMobil2, 2013, Pillath, 2016, Frisoni et al., 2016 et al.). Further legal recognition of AV is expected (Raptis, 2017) and necessary in order for “true” benefits of automation to be more visible to the society.

4.7.2. National law

At national level, a vast amount of countries like Greece, Denmark, Germany, France, UAE and so forth allow or are about to allow in the near future fully-autonomous vehicle trials (Holm, 2017a,b, CityMobil2, 2016b et al.). At the same time commercially available semi-autonomous cars, offered by many manufacturers, Mercedes Benz, Tesla and BMW (Car and Driver website, 2016) embed a vast array of ADAS like autopilot, LKA, which are also allowed in a large part of the world. Various interpretations of VCRT are used around different countries of the world. However, liability in all cases lies either with the physical driver, in the case of a semi-autonomous car, or with the remote operator, in the case of the fully driverless pod (Raptis, 2017, CityMobil2, 2013). Discussions concerning switching responsibility from the driver to car manufacturer or other car-related human (or non-human) parties are still at an immature stage, both on a national and international scale (Egense, 2017, Lange, 2017 et al.). This is partly because driving automation technology is believed not to be 100% ready to perform entire driving task under all conditions (Lange, 2017 , Raptis, 2017 et al.), as also pointed out in the recent Tesla accident (Forbes website, 2016, Reuters website, 2016 et al.). Therefore redefinition of legislation or redistribution of liability should proceed in accordance with - the steady though - progress in making AV capable of undertaking more parts of the driving task (Collingwood, 2017).

4.7.3. Ethics

AV will lead to a substantial increase of safety both for their passengers and other road users; yet some accidents will still happen (Goodall, 2014). Reaction of the AV when an accident is foreseen will not be shaped *in situ* by the driver, but a priori by a programmer. This raises an amount of ethical and operational concerns. Ethics refer to which practical, moral etc. criteria AV will be based on for decision-making in critical situations. These issues have not been defined yet (Egense, 2017, Kyed, 2017a, Lange, 2017 et al.) and respective dialogue could be expected to proceed when automation technology will be safe enough to move - at least parts of - responsibility from the driver to the car (Lange, 2017). One of the most common situations of this kind are the “trolley-problems”. These problems refer to situations where an accident is inevitable and there is somebody inside or outside the vehicle, who has the possibility to decide who will be hurt – more than another -, by somehow affecting vehicle’s movement (Sandel, 2009, p. 41). Two examples of trolley-problems follow.

Image 8: "Trolley-problems: Do we have the right (or even obligation) to sacrifice one person in order to save five?"

Source: Vasilogiannis, 2014 p.41

A tram (here referred as trolley), whose brakes are out of order, is heading downhill and is about to enter a station. If it proceeds to the main line it will kill five people, who are tied on its tracks. However, there is a branch line where a maintenance worker does his job. A pedestrian stands in front of the switch, which can make the train turn to the branch and kill the line worker instead of the five people (Sandel, 2009, p.37-41). Is this person entitled of deciding who and how many people will be killed by the tram? What should he/she do if he/she was not a random person but the station master? There is a wide spectrum of answers in this question, depending on the perspective adopted, the role of each agent etc.. In another example, a child crosses the street carelessly, while on the other pavement an old woman is walking inside the designated area. An AV is coming at a normal speed, but distance to the child is so close that accident is inevitable. AV has the option of running over either the child or the old woman. One could argue that it is more important to save child's life, as old woman has been already living for a long period of time. Another point of view could be that since the old woman abides fully by the law, why should she be killed because somebody has acted improperly? Dilemmas on how a human or nun-human entity is allowed to assign right of life and how they should do it are numerous and in many cases finding an answer is rather difficult. For that reason and in order for power distribution to be fair and socially accepted, design and programming of those reactions shall not be one or two parties (car manufacturer etc.) (Lange, 2017). Policy makers should assure highest level of social involvement in this process, either directly or through society's representatives (political institutions/experts etc.).

Operational dimension of the change in who and when decides how an accident will evolve has to do with two things. First the car will rely on its sensors, radars etc. for identification of driving environment, therefore quality and capabilities of this equipment are crucial in order to have a quick and successful reaction. Second the vehicle will have been programmed to react in a more "calm" way than the driver would do a few seconds before crashing, which means its reaction may be more optimum than the one of the driver involved in the incident (Goodall, 2014).

4.8.Epilogue

Driverless mobilities will fill the gaps between existing forms of mobilities, namely public, private and active, thus achieving greater efficiency and sustainability. This will happen first through providing the possibility for a notable cost reduction, accruing from the lack of driver; and second by enabling fundamentally increased flexibility in the allocation of mobilities' resources. Moreover, they will allow a substantial increase in safety, by removing human error from driving. However, considerable concerns arise regarding their impact on congestion, security, liability and ethics; which should be addressed in detail before driverless mobilities are more widely implemented. In spite of the fact that shared AV will make "car"-mobilities easier by e.g. alleviating the cost of obtaining a car and the need of having driving skills, it is not sure that driverless mobilities will actually be a service for all. This is because access to a wide part of resources needed for driverless mobilities to be performed (vehicles, energy etc.) will still be limited, therefore there should be some sort of selection mechanisms, according to the logic of the system. Hence, question on if AV will eventually be a service for all cannot be answered, until criteria that this mechanism will follow in order to assign access to AV system are defined. Main barriers in the establishment of driverless mobilities at the moment can be considered the readiness of driverless technology to work in real-life situations and lack of relevant legal framework. Contrariwise, society could be regarded as willing to experiment with this innovation, while driverless technology has proved to be quite capable of working in controlled environments. Therefore extensive demonstrations and applications of this new system should take place, so that society has the possibility to see its benefits, technology has the opportunity to “learn” from its experience and nations get more motivated to take a step ahead in the legal recognition of the system. These applications can refer to services that are not practically or economically feasible with conventional PT, such as last mile services or intra-campus shuttles. In the next chapter, empirical evidence on the modus operandi of driverless mobilities will be gained. This will take place through the examination of two cases where driverless mobilities have been practiced in Aalborg, Denmark and Trikala, Greece. Review of those cases will allow valuable considerations on which benefits driverless technology can bring in practice as well as the practical, technological, political, legal and societal challenges that the implementation of this new form of mobilities has to face.

5. DRIVERLESS MOBILITIES IN PRACTICE: EVIDENCE FROM AALBORG EAST, DENMARK AND TRIKALA, GREECE

After a discussion of if, how, why and to which extent driverless mobilities should be implemented in the previous chapter, it is examined how this technology can work in practice. In this chapter two efforts to illustrate possibilities of this new technology, in Aalborg East, Denmark and Trikala, Greece, will be analyzed. First project intends to fill the gaps of PT and enhance social inclusion in the area through AV service. Second case refers to the first time AV ran into public streets, overcoming a wide range of technical, legal and practical obstacles.

5.1. Implementing "neighborhood" mobilities with AV in Aalborg East

In previous chapter it was noticed that people will be far more willing to experiment with this new technology if it offers them an important new possibility compared to existing mobilities system. One of these possibilities could be the frequent connection of different parts of a community with each other, local centres and transit hubs, which in this project is named "neighborhood mobilities". Existing PT systems do not always offer this possibility, especially where residential densities are low. Lack of this service could be attributed to restricted flexibility of conventional PT vehicles, high operational costs and disproportionately low demand (Ryley et al., 2014, Koffman et al., 2004). AV can play a dominant role here, as lack of driver's wage as well as the use of electricity may revolutionize economics of this type of mobilities, by making this type of mobilities feasible even when passenger volume is low. Aalborg East is an area where this alternative may offer substantial benefits, as mobilities might be not so smooth for a part of the population, such as the elderly, while car ownership rates are low. At the same time bus lines approaching the area are radial; hence, even if they offer quite good service to Aalborg Central Business District (CBD), they neither cover all intra-community routes nor connect all parts of the area with Aalborg University (AAU) campus.

> *I think it (driverless bus) provides us first of all a new type of mobilities. I think this kind of technology will give us a better option to use existing infrastructure we have. So I think we can have some good options, and maybe also cheaper, that vehicles we have today are not able to provide (Holm, 2017a).*

Therefore, Aalborg East is a district where testing AV technologies may significantly raise its mobilities *capital*, produce high added value to local society and enhance overall development prospects of the district. Planned driverless bus test service will be launched in 2018 and serve north-south axis of the district, connecting residential areas with local centres and in the future linking the entire district with AAU main campus and proposed Bus Rapid Transit (BRT) line (Holm, 2017a,b).

5.1.1. The way to the legal recognition of AV

Realization of driverless mobilities in Denmark was made feasible by the Bill L 120 A of 25.1.2017, which came into effect on 1 July and allowed AV trials on public streets. Trials take place for a period of two years, which can be extended to five years. During this period, trials are evaluated two times:

> *Within two years of the entry into force of the test scheme, an evaluation of the experience with administration of applications, etc. will be prepared. (...) The evaluation provides the basis for a political assessment of whether there is a need to adapt the administrative aspects of the test scheme in the light of the experience gained at this time. Within five years of the entry into force of the test scheme, a final evaluation of the scheme, which will form the basis for a political assessment of whether the scheme is to continue unchanged, will be repealed or shall provide a basis for a permanent regulation of driving with Self-propelled vehicles in Denmark (Danish Ministry of Transport, Building and Housing, 2017, translated from Danish).*

Institutions, companies etc. who would like to run an AV trial should apply to the Ministry of Transport, Building and Housing. Applications are reviewed by either Danish Road Directorate or Municipalities, depending which authority the road belongs to; by police; by Danish Road Safety Agency; by Danish Parliament’s Transport, Building and Housing committee and by an internal assessor (Danish Ministry of Transport, Building and Housing, 2017, translated from Danish). Conditions and characteristics of each specific trial are configured by the Minister of Transport, Building and Housing (Bill L 120 A of 25.1.2017 § 92 h.).

Vehicles must have either a physical person on board the vehicle to take over control of it, if necessary, or a remote operator who monitors vehicle's movement at all the time. Physical person must be able to:

> *(...) take over the lead when instructed by the technical device of the self-propelled vehicle or when the physical person considers that there is a need for this (Bill L 120 A of 25.1.2017 § 92 g. par. 3).*

Moreover:

> *The physical person must have acquired a driving license for the vehicle category in question and must comply with the rules for spirits and driving under the influence of awareness-raising substances in sections 53 and 54 (Bill L 120 A of 25.1.2017 § 92 g. par. 3).*

Operator has is legally treated the same as the physical driver:

> *An operator refers to a natural person participating in the test but not present in the vehicle during the journey (Bill L 120 A of 25.1.2017 § 92 g. par. 4).*

Remote operator is the same as responsible for vehicle's movement as a potential physical driver:

> *The bill entails that self-propelled vehicles under the test scheme will be subject to the provisions of the Road Traffic Act on Insurance and Objective Liability, although the liability lies with the license holder and not the owner / user of the vehicle. This applies regardless of whether the motor vehicle is driven by a physical person, an operator or the technical device (Bill L 120 A of 25.1.2017, comments 3.2.3.)*

5.1.2. AV pave the way for a "more sustainable town" and a "strong Municipality"

Aalborg East is a suburb of Aalborg, 7 kilometers away from the city centre and belongs to the Region of Northern Jutland in Denmark. Around 15.000 people live here, while it features Aalborg University main campus in its southern part. There are two local centres in the area Planetcentret and Tornhøjcentret; offering local scale shopping and recreation facilities (personal observation, 2017). The area is connected with city centre by bus and lies 1,5 km away from E45 motorway. Astrupstien corridor, where the bus will run, is a north-south axis, serving a significant part of the district and two local centres.

Project, or the "Astrupstien link", will begin in 2018 and will be carried out by Aalborg Municipality, NT, Aalborg University and Keolis (public transport operator). In the first form of the project buses will run from the northern part of the district (Jerupstien) to the local shopping and recreation centre in Smedegårdsvej, finally reaching Trekanten Cultural community centre and Library in Humlebakken. In the second phase service will be expanded to Øster Uttrup Vej in the north and Aalborg University (AAU) main campus in the south. In the AAU campus there will be connection with +BUS (planned BRT line) to the city centre and new University hospital. Initial stretch will be 2,1 km long and total length of envisioned route will be approximately four kilometers. Buses used will be the 15-seat driverless pods "Navya Arma" (TV2 News, 2017 - see image 11).

Figure 4: Map of Aalborg, including +BUS and Astrupstien link's visionary form

Source: Own editing on google maps background

Image 9: Planetcentret and kindergarten at Aalborg East

Source: personal archive

Driverless bus project will be part of a wider urban development project which aims at making Aalborg East *a more sustainable and coherent town (Aalborg Municipality website, 2017a, translated from Danish).* This project includes creation of 3000-4000 new dwellings in different phases, enrichment of public facilities (health centre, swimming pools etc.) and construction of a new office complex (Aalborg Municipality website, 2017a). Astrupstien path, where driverless bus will run, will be the backbone of revitalized district (see image 10), while Tornhøj local centre will be the new main local centre of the area (Kickstart Forstaden, 2014).

Image 10: Illustration of Humlebakken tunnel with driverless bus

Source: Team Vandkunsten website, 2017

Image 11: Driverless pod “Navya Arma”of the Aalborg East project

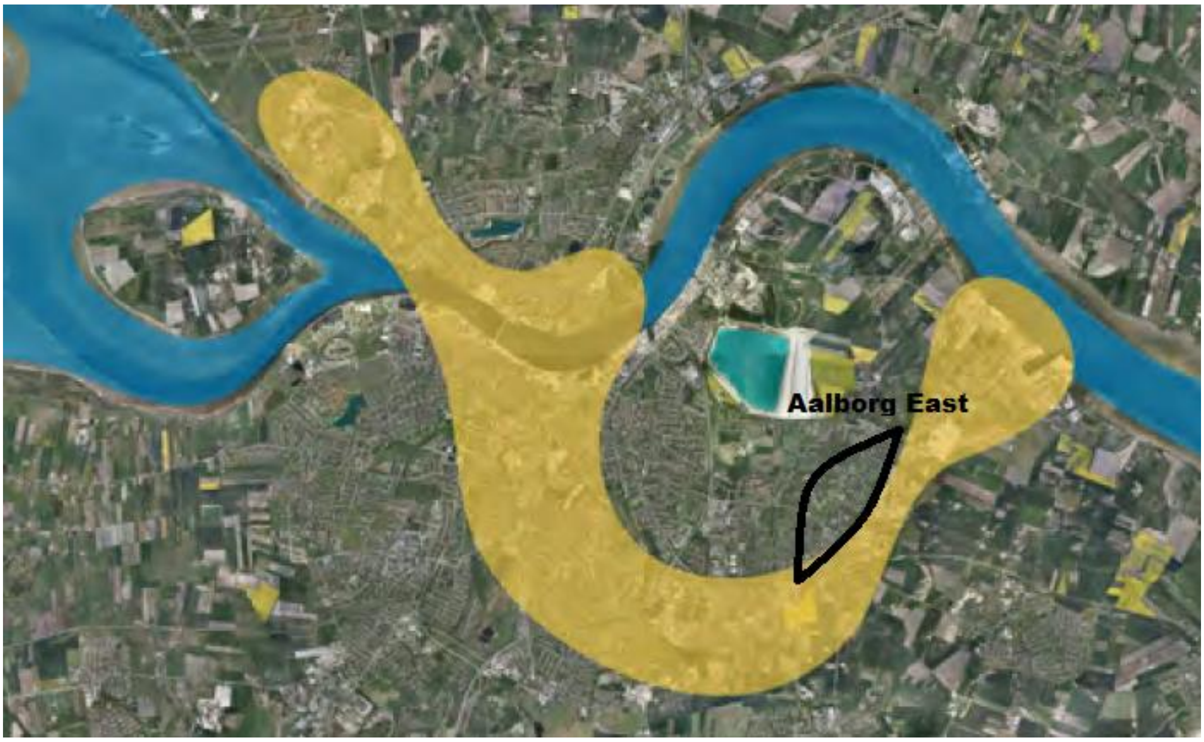
Source: Video screenshot from TV2 news, 2017

Project is a part of “spatial vision 2025”, which acts as the umbrella of all urban development projects in the city (Aalborg Municipality, 2013, translated from Danish).

> *The goal is to secure the future of a strong city and a strong municipality; to integrate the growth and prosperity into new holistic, urban contexts (Aalborg Municipality website, 2017b, translated from Danish).*

Some of the main scopes of the strategy are to enhance living conditions and mobilities in the city as well as to accommodate rising housing demand (Aalborg Municipality website, 2017b, translated from Danish). In a greater sense, it endeavors to facilitate the already begun transition from an industrial economy to a “modern knowledge city with a global perspective” (Aalborg University website, 2017, Kamp et al., 2016). Backbone of this process will be the “Aalborg growth corridor”, which is which is the area including airport, city centre, Aalborg University, new university hospital and East (commercial) port (Aalborg Municipality, 2013, translated from Danish). Aalborg East is the immediate vicinity of the corridor, so it can be widely benefited by the opportunities this axis will bring.

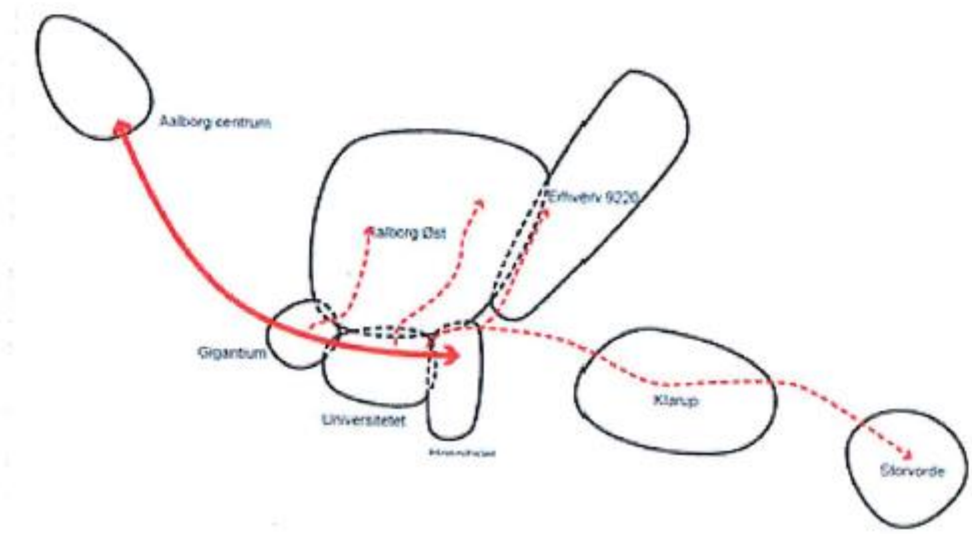
Figure 5: Aalborg growth corridor



Corridor: Yellow shading

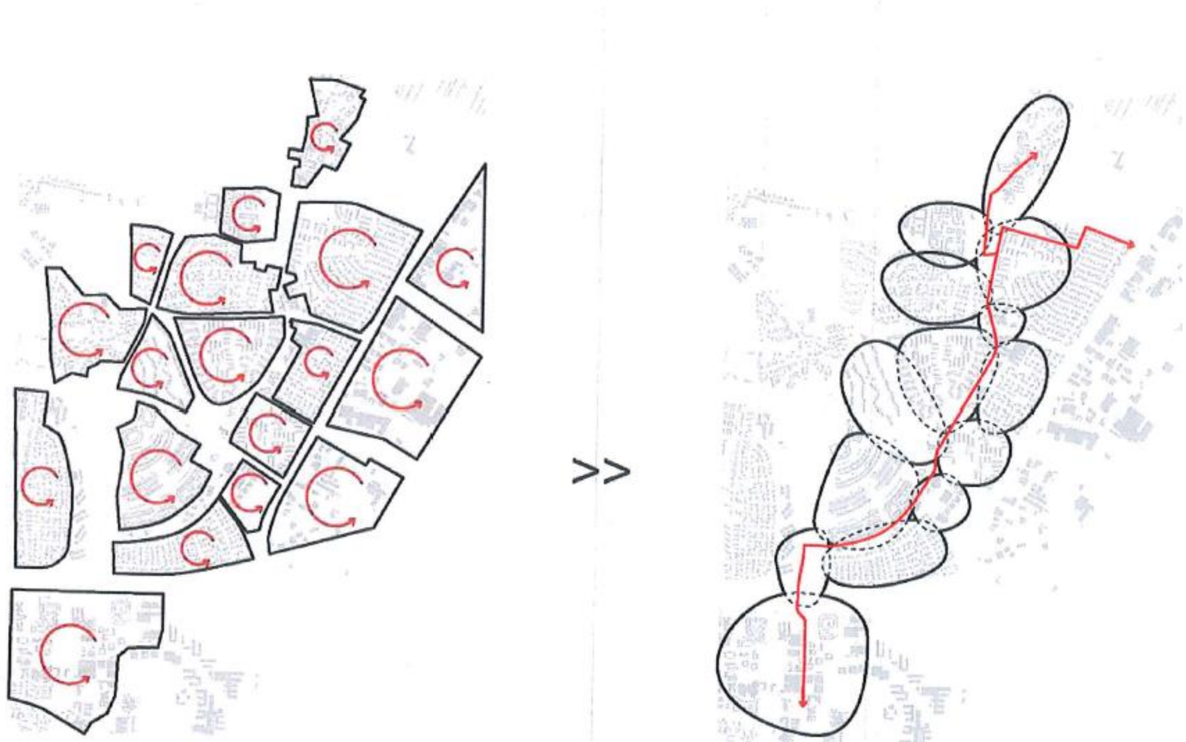
Source: Aalborg Municipality, 2012

Figure 6: Connecting Aalborg East with the rest of the city



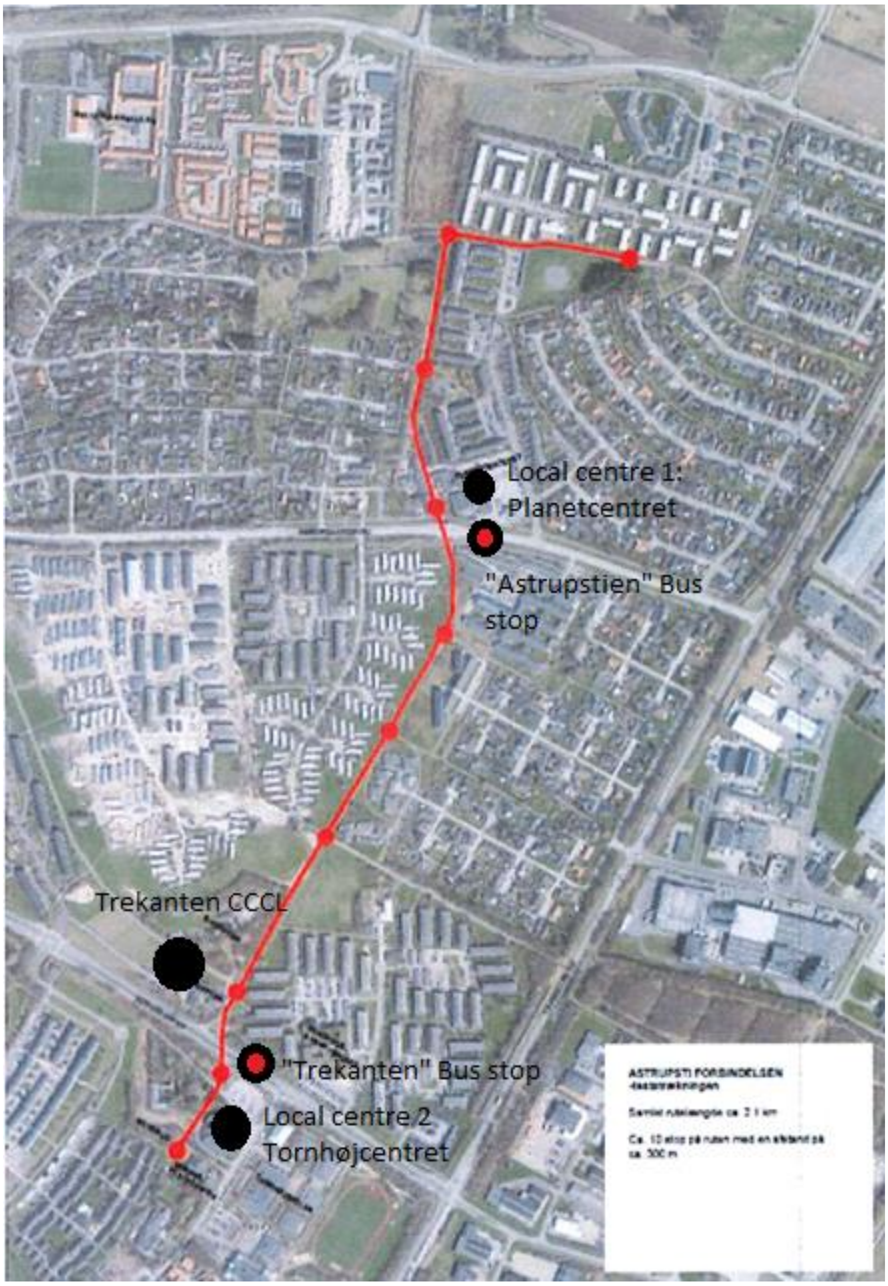
Source: Holm, 2017b

Figure 7: New spatial development paradigms: *Separated islands turn inward (left); new connections bring islands together (right) (Holm, 2017b, translated from Danish)*



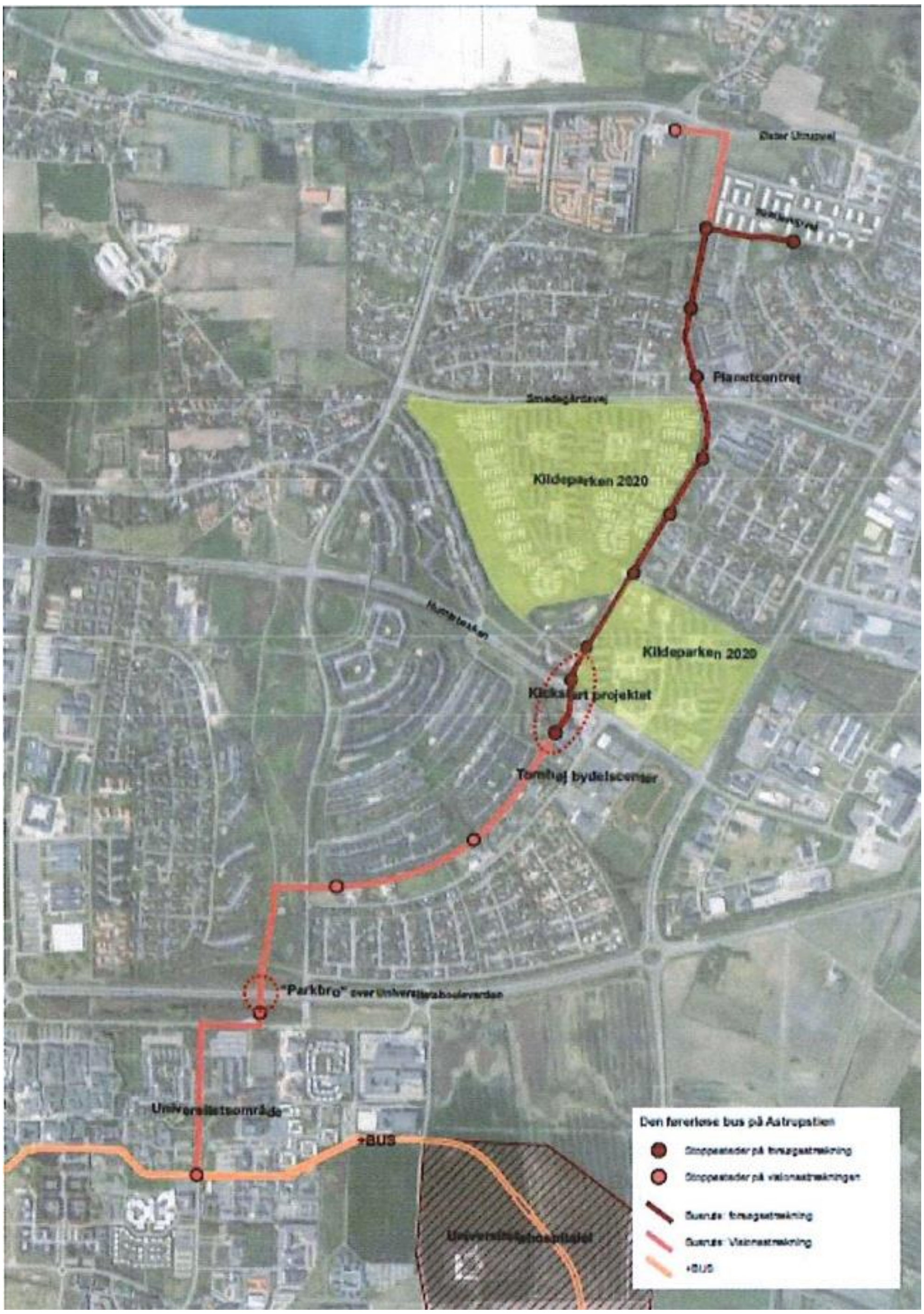
Source: Holm, 2017b

Figure 8: Aalborg East driverless bus, phase 1



Source: Own edit on Holm, 2017b

Figure 9: Aalborg East driverless bus vision route and Tornhøj local centre (red circle)



Source: Holm, 2017b

The area was firstly built in the middle of 20th century in order to accommodate the rising industrial population of the city (Lanng et al., 2012). Largest part of housing development in the area though took place in the 70's, when building patterns were prioritizing high urban density over sufficient public infrastructure and green areas (Holm, 2017b). Public facilities and infrastructure are greatly dispersed and underexploited, thus not offering their most to local population (Holm, 2017b). Spatial structure is based on the concept of functionalism, described in International Congress on Modern Architecture (CIAM) Athens Charter of 1933; hence segregation between residential uses and service/business facilities is in the greater part of the district clear (Lanng et al., 2012). In line with this, formation of mobilities networks in the area is substantially influenced by the Swedish "City Building, Chalmers, Working Group for Traffic Safety (SCAFT)" guidelines of 1968, where it is highlighted that friction between motorized and non-motorized traffic should be kept at lowest possible levels (Lanng et al., 2012). Swedish SCAFT guidelines on road planning are stated below:

> *localization of industries and service facilities in relation to access via primary traffic connections; 2) segregation of motorized traffic from pedestrians and bicyclists in different systems which do not intersect; 3) differentiation of traffic means and speed within each traffic system; and 4) clarity, simplicity and uniformity in the design of the traffic environment (Lanng et al., 2012).*

Segregation of those different traffic flows allows substantially greater traffic safety, especially for the more vulnerable road users pedestrians and cyclists, thus also affecting positively the attractiveness of active transport. Minimization of friction between different systems of transportation may affect the success of the AV project positively, by both enhancing safety along AV's path and limiting accelerations and decelerations on AV's movement. At the same time, clarity in the distinction between different transportation systems will make clear which is the route of the AV to road users; therefore local society may get more easily used to it.

5.1.3. Autonomy in practice

An *ambitious*, as Holm (2017a) portrays it, part of the project is that there will not be any person on board, but only a remote operator. Since fully unmanned operation is by definition the next step of driverless mobilities, adopting that modus operandi in this test will produce valuable conclusions regarding societal readiness to take a step forward. However, the fact that Danish society is considered to be more open to experiment with new technologies (European Commission, 2012) does not make success of this choice profound. This is exactly because an important amount of Aalborg East' residents either comes from other – in many cases Eastern – countries, so they might have not the same technological experiences, or are elderly, who may – still - be more reluctant to try fully driverless mode (Hohenberger et al., 2016). Nonetheless, preliminary indications are positive:

> *People were more reluctant before a few years than they are today. In 2014, we were asking them "Could you imagine that you would drive with this kind of the bus where there is no driver?" and most people said "oh yes, I would do that". I don't think they could exactly imagine what they were saying yes to but they were willing to do something even though they did not have exact image of it and I think today you may find even more people saying yes, no problem (Holm, 2017a).*

Driverless bus, which will be electric, will of course be motorized but it will move at a cyclist's speed on the bike lane, thus conflicting SCAFT guidelines 2 and 3 (see previous section). Therefore it could be assumed driverless bus introduces a new philosophy of "integration" of various traffic flows, which comes in contrast with the existing "optimum" one of segregation. Alternatively it could be regarded as the middle scale, or a "Hybrid", between "heavy" motorized traffic (cars, buses etc.) and non-motorized one. In this concept safety is not "staged from above", which means that it is not a result of some road planning patterns, but it will be achieved "from below", namely through coordination among users of the corridor the driverless bus, cyclists and pedestrians. In this "stage" pedestrians will have their own space, while cyclists will share the path with the bus. So, as the bus will be relatively faster than cyclists there will be cases where it will be behind them and they will have to allow it to overtake them. Then the bus will identify cyclists' movement through sensors and cameras it will have and when the way is clear it will proceed. Therefore speed and reliability of the bus will largely depend on cyclists' attitude towards it. Taking into account that something like happens for first time, so cyclists are not used to it, it would be rather interesting to examine how cyclists will engage with the bus in such cases:

> *This (feature) will be interesting because we'll see how polite will cyclists be. They may be so polite that when they see a bus coming they move back, for the bus to pass, we'll see. Otherwise the bus will stop and cyclists will pass (Holm, 2017a).*

Coordination of cyclists and bus will encounter some difficulties, especially at the beginning. For instance, driverless bus radars may be more sensitive towards following obstacles (e.g.

branches) and break more frequently and/or harshly than the cyclist, leading to a rear-end collision. Alternatively, if bus is overtaking a bike but the cyclist has not realized that and moves for some reason to the left side of the path carelessly, collision may also happen, regardless of driving reflexes of the bus. Therefore, despite the fact that bus speed will be comparable to the one of the bikes, namely 20 km/h at the beginning and up to 30 km/h later, possibility for accident is still non-negligible. Therefore, extensive education and awareness campaigns should take place in order to make sure both frequent and non-frequent users have knowledge of new modus operandi of the corridor.

Image 12: Astupstien tunnel under Smedegårdsvej, near Planetcentret

Source: Personal archive

Image 13: “New Aalborg East” under construction together with Astrupstien link

Source: Personal archive

5.1.4. Uniting people through (better) mobilities

Astrupstien corridor is located in an area where a notable part of the population has fewer mobility options. Lack in sufficient mobilities can induce social instability, as it can restrict access to job opportunities, prevent social interaction (Grengs, 2004) or possibly limit opportunities for recreation and personal development. In Aalborg East car ownership rates are low, partly because of low income levels, while there are many people that might have weaker mobilities competencies. These are elderly, who may travel to local markets or bus stops; children going to school or local recreation facilities and disabled, who are going to nearby institutions. Therefore bus has a strong social role in the area. Another component of its social role is to enhance social inclusion not through improved mobilities but by becoming a “symbol” and a critical component of the area:

> *The trial is not just to test the technology. It's also to test how are people looking at his kind of technology. Can we integrate this kind of technology in an area where people feel connected with and protecting this kind of technology? Can we also engage the youth?(...) There are a lot of different kinds of elements in the test. (Holm, 2017a)*

In specific, it aims at Aalborg East a "first mover" in driverless technology; hence to be a cause of pride for local inhabitants. Furthermore, many possibilities are examined, so that local residents create a sense of "ownership" towards the bus. These possibilities include but are not limited to having it painted by professional graffiti painters; or to conduct competitions in order to give the buses names. This way, if Aalborg East could be imagined as a puzzle, it is intended that bus will become a part of the area's puzzle not only by connecting components of the puzzle more smoothly but also by improving the image of the entire puzzle. One could argue that research on if driverless mobilities, or another new feature, can constitute a means of improving place's identity did not specifically have to take place in Aalborg East; or in an area which is under some form of pressure in general. However, as Holm (2017a) highlights:

> *I think usually when you give people an option they didn't have before they are more grateful to take it. It's no sense in putting this kind of mode in an area (...) where people have very expensive cars. They will say ok... even though they are the first movers.*

Operationally, Aalborg East project, at least in the first phase, will be distinguished from regular PT service, provided by NT. However, if test succeeds, driverless bus line will be integrated with the existing system by being a part of trip options, offered by NT's trip planning app Rejseplanen, as well as potentially by having the same pricing scheme (Sørensen, 2017). This integrated mobilities service will offer an even better experience to local people, as well as it will support the role of PT in the area.

Image 14: “Thank you for not smoking inside the bus stop cabin” in “Trekanten” bus stop in Humlebakken.

Source: Personal archive

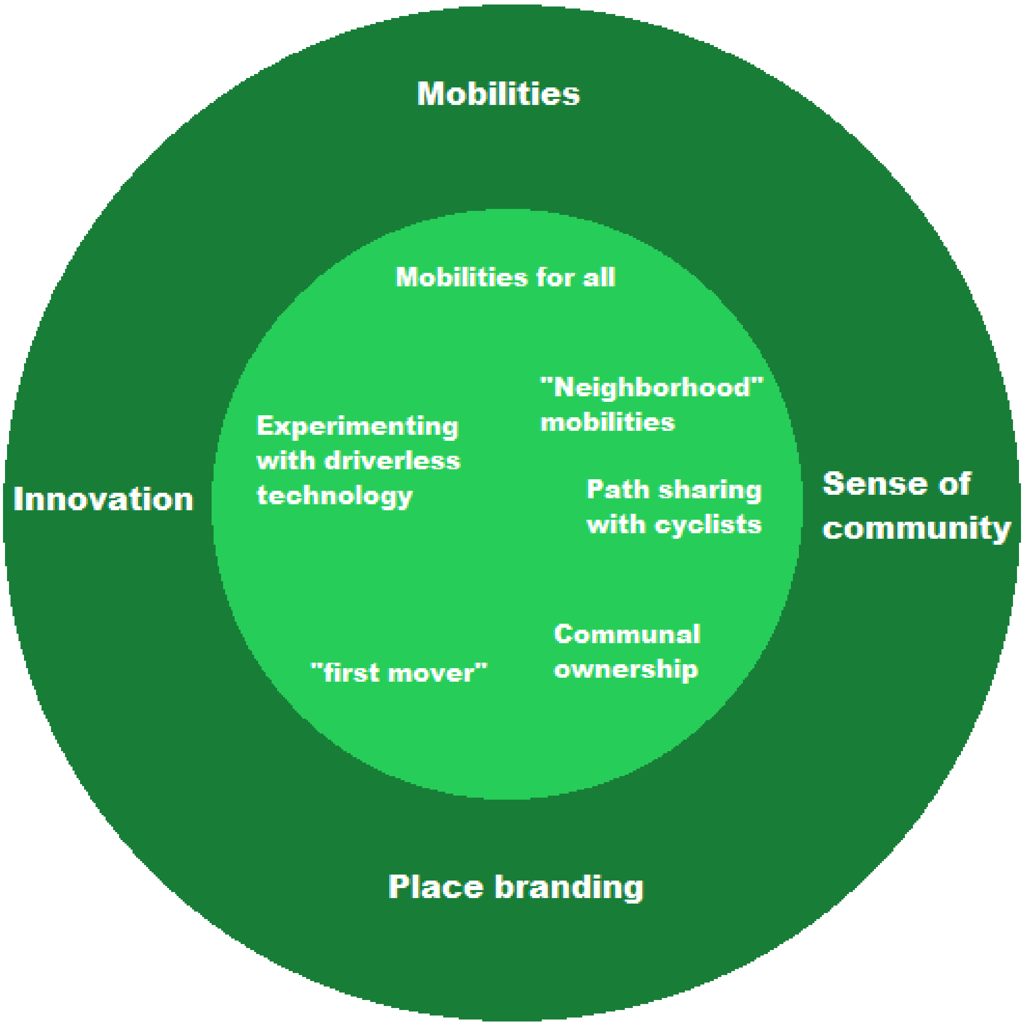
5.1.5. A different meaning for Aalborg East

Following Lassen’s mobile definition of place (2016) it could be supported driverless bus comes to Aalborg East in order to enrich the “meaning” of the area as well as to improve local mobilities. Project will also pose an – indirect this time - effect on place’s materiality as a number of new facilities (new Tornhøj local centre etc.) are linked to it; thus shaping a new spatial structure for the area.

Place = Locality + Materiality + Meaning + Power + Mobilities (Lassen, 2016)

All those components interact with each other and shape place’s function, identity and prospects. Aalborg East’ proximity to Aalborg University Campus and future hospital (location) will be more “fruitful” for the area after driverless bus connects it with those facilities (mobilities). Moreover, cultural mix and liveliness of the area (meaning) may also be improved, as driverless bus shuttle service to the university (mobilities) may increase attractiveness of the area to students. This in turn will possibly introduce new citizen's collectivities as well as new forms of urban government, embracing more participatory decision-making processes (power).

Figure 10: Elements of driverless bus project in Aalborg East



Source: own editing

In the illustration above, elements of Aalborg East driverless bus project are depicted inside the circle, while they are categorized according to the domain they are more related to; namely mobilities, innovation, place branding and sense of community. In particular, "neighborhood" mobilities, performed by driverless bus and path sharing with cyclists not only fall under the domain of mobilities but also support sense of community in the area.

Respectively, communal ownership does not only sustain sense of community in the area but also builds a stronger place brand. This is because it could be argued that strong attachment of local population to a common object, value or achievement, such as the driverless bus, can be of critical importance in building a successful brand for the area. At the same time, being a test bed for driverless technology fulfills three purposes. First it will generate knowledge about strengths and weaknesses of new technologies, thus facilitating technological diffusion in the domain of mobilities. Second it will add the "first mover" element to Aalborg East brand, while it meets the scopes of making Aalborg an innovation-friendly city with global perspective.

5.1.6. Epilogue

Aalborg East driverless bus project is intended to achieve a wide spectrum of goals in enhancing mobilities in the area, supporting social inclusion and aiding greater urban regeneration efforts. Being one of the first cases globally and a forerunner in Denmark, along with Vesthimmerland Municipality, in offering regular mobilities service with AV comes with many expectations as well as risks. Even if there is no input based on events about this project, some interesting conclusions regarding its design could be the following. First, when innovating, as the world of aviation widely stresses "safety (goes) first". As previously mentioned "*A post-car system will need to be at least as effective as the current car"* (Dennis and Urry, 2009), where term "effective" does not exclude safety. In this case, driverless buses will operate at low speed, run in a corridor with no other forms of motorized traffic and will be light, which may lead to shorter braking distances compared to ordinary vehicles. Contrariwise, coexistence of driverless bus and cyclists may be a kind of challenge, as it will be first time cyclists face this kind of traffic in bike lanes. Nevertheless, taking into account that involving low speed driverless buses with ordinary traffic will presumably pose remarkable threats, it could be assumed Astrupstien is one of the safest environments for driverless technology to be tested. Second, from a law perspective, Aalborg East will also be a "first mover", along with Vesthimmerland Municipality, but in this field, many questions remain to be answered after related legal framework has been formulated. Those have to do with modus operandi of the service, safety regulations, liability and ethics in case of an (foreseeable) accident. It should be noticed this is an initial form of the regulatory framework for driverless mobilities, and refers only to trials of this new technology. Therefore, final law about regular use of AV may address aforementioned issues in a different way than this law will do. Third remark has to do with the field where the project will take place in Aalborg East. This area could be characterized as a “fertile ground” for the introduction of new forms of mobilities due to the physical mobility constraints a part of the population faces and low car ownership rates. In specific, people there will be more willing to try an alternative mobilities option, as long as it offers a possibility, which was not available before. This way, advantages of this new technology may be perceived by a greater part of the population as well, while there would be richer feedback by the public on how this innovation should be further developed in order to better meet their needs. Success of this project will substantially enhance mobilities in Aalborg East, while it will constitute an important source of knowledge on how to implement driverless mobilities, not only on national but also on international scale.

In this chapter it is analyzed how AV can contribute to better mobilities, social cohesion and place branding in Aalborg East, as well as which challenges it endeavors to prevail over. Following chapter discusses the contribution to the readiness of driverless technology to undertake such a “responsibility”, coming out of an AV demonstration in Trikala, Greece in 2015. At the same time it is illustrated how this demonstration also enhanced sense of community, highlighting capability of driverless mobilities to deliver social goals.

5.2.Rolling AV out onto public streets for first time: Trikala project

> *You got a baby, you taught it to walk and you made it an adolescent, ready to get on the streets (A. Alessandrini, coordinator of CityMobil2 project, addressing D. Papastergiou, Mayor of Trikala. Source: myota website, 2016).*

Road for making driverless mobilities feasible will not be paved until it is assured AV can safely operate in public streets. Moreover, as seen in respective scientific etc. evidence (see chapter 4.5.) technological readiness is one of the dominant concerns of the public towards this kind of mobilities. Therefore, progress done in this field should not only “be kept” in the test track but also demonstrated and communicated extensively, in order for society to be convinced these vehicles can safely be part of their mobilities patterns. Until 2015, AV were tested only in guideways fully separated from other traffic, or at the presence of a driver who had full vehicle control equipment (steering wheel, pedals etc.) (CityMobil2, 2016b, Alessandrini, 2015b et al.). Therefore, questions regarding their interaction with other motorized or non-motorized traffic or people’s attitudes towards fully automated driving mode were still unanswered. In August, 2015 though, small electric driverless buses, or Automated Road Transport Systems (ARTS), run for first time in mixed traffic, without carrying vehicle control equipment. Demonstration took place in Trikala, a medium sized city in Greece and lasted 6 months, as a large-scale demo of a project CityMobil2, which is carried out by European Union (EU). Project partner in Trikala was Trikala Municipality Development Company "E-Trikala" SA, while demonstration was also supported by Region of Thessaly. During that demonstration, benefits of driverless technology were highlighted; readiness of ARTS to be rolled out onto public streets was examined and improved; challenges of movement in urban environments were addressed; and valuable feedback by users, residents, authorities and other stakeholders of the city was gained (Raptis, 2017, CityMobil2, 2016b et al.). Demonstration is considered as rather successful (Council of the EU, 2016, National Geographic News website, 2016 et al.), while attitude of the public was overwhelmingly positive (CityMobil2, 2016a et al.).

5.2.1. AV as a part of the city's inclination to innovate

Trikala is located at the Region of Thessaly in Central Greece and has a population of 81.355 people (2011) (Municipality of Trikala, 2015). Trikala is one of the most innovative cities in Greece, carrying successfully out a vast array of projects for smart and sustainable development through disruptive innovation (Greek Ministry of Interior, Decentralization and Electronic Governance, 2010, Urban and Regional Innovation Research, 2008, Fortune Greece website, 2017, et al.). Implementing authority of this kind of projects is E-Trikala SA, which was founded in 2008 and followed the Information Society office of the Directorate of the Municipality of Trikala. Fields of interest of the company include but are not limited to e-democracy and governance; providing broadband internet access for residents and visitors of the city (Wifi, fiber optics, Wi-Max), telehealth, smart mobility, Geographic Information System (GIS) as well as tourist e-information and e-services (Municipality of Trikala old website, 2017). After predecessor office took its first initiatives in 2004, in a rather analog age for the country, city of Trikala was named as "the first digital city of Greece" by the minister of economics (Molonis and Bletsas, 2016, Localit.gr, 2015). City was also included in Smart21 network of the Intelligent Community Forum (ICF) for three consequent years 2009, 2010 and 2011 (ICF website, 2017).

> *We envision to become an official test bed for technological innovations. We aim at the added value this role will bring to the city, and we're aiming at high added value innovation (Raptis, 2017).*

Driverless bus project – or demonstration - was exactly part of that vision. Trikala endeavored to demonstrate how driverless technology works in practice, as well as to make it more "mature" to undertake "real life" assignments, such as to deal with the last mile problem (Raptis, 2017, Karaberi, 2017, Vavitsas, 2017).

Image 15: Trikala city centre

Source: personal archive

In Trikala, considerable efforts to support sustainable mobilities take place. In particular, mobilities practices involve cycling to a significant degree, thus establishing a kind of "bike culture" [Podilates Trikalon *(Trikala cyclists)* website, 2017, Patras events website, 2014 own translation from Greek]. At the same time, a wide range of project on the materialization of smart mobilities (Intelligent traffic data analysis system, real-time information on bus traffic etc.) has been conducted (E-Trikala SA, 2017). Moreover, Trikala is one of the first cities in Greece where local mobilities will be planned using the newly developed concept of the Sustainable Urban Mobility Plan (SUMP), instead of a conventional traffic plan, following a much more holistic and sustainability-oriented planning approach (European Commission website, 2016, Trikalain.gr, 2017). Therefore, demonstration could also be regarded as a part of this tradition. CityMobil2 demonstration will be followed by participation in CityMobil4 project, where private car-sized AV will be released to the streets in order to connect low density areas with local transit hubs and other uses. In the next period of time small driverless vans will also be introduced, so that urban logistics will be performed at 24 hours per day and at a drastically lower cost (Raptis, 2017).

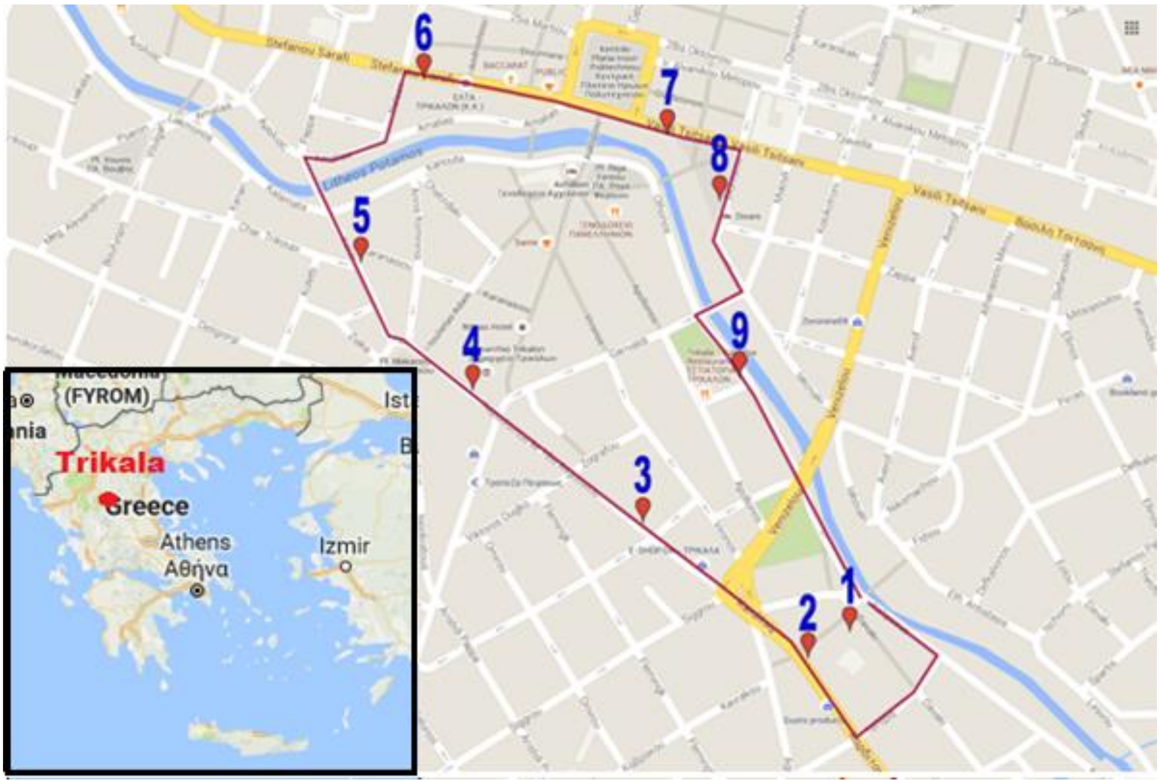
Demonstration took place between August, 2015 (pre-testing period) and February, 2016. Initially there was a person from the company present at the vehicle but later operation was fully unmanned (Karaberi, 2016).

Figure 11: Timeline of Trikala project

Source: Karaberi, 2016

Driverless bus was operating in a 2,4 km circular route in the city centre of Trikala and had nine stops. City was given six 11-seat vehicles (6 seated passengers, 4 standing and one wheelchair user), while service was running every 30 minutes from 10.00 to 14.00 and from 17.00 to 21.00 every day except from Monday. Bus route was passing through the largest part of CBD, residential and business uses as well as all main sights of the city (Vavitsas, 2017).

Figure 12: Map of driverless bus route



Source: E-Trikala, 2015 (bus route) and own editing on google maps background (for the location of Trikala city in Greece)

Image 16: Semiotics of driverless mobilities:"Bus lane - Lane is exclusively used by autonomous vehicles".

Source: Karaberi, 2016

City Mobil2 programme was coordinated by Sapienza University of Rome, was financially supported by European Union (EU) and intended at demonstrating ARTS in European streets:

> *The main project achievements, besides having the vehicles operational and the passengers transported, are to have defined the "safe way" to integrate automated transport in urban streets; not relying on the vehicle technology only but relying on a continuous cooperation with the infrastructure (CityMobil2, 2016b).*

Project took place between 2012 and 2016, involving 45 partners and 12 cities; while 3- to 6-month demonstrations took place in 7 of them.

Figure 13: CityMobil2 demonstration areas

Blue: large scale demo; light blue: small scale demo; green, orange: showcase

Source: CityMobil2, 2016b

5.2.2. The marathon of establishing legislation for AV

Implementation of the demonstration in Trikala had to face a vast array of difficulties and challenges. Primarily, Greek legislation did not feature any provision for driverless vehicles. As in most similar cases, at least in European level, main barrier for amendment of existing law was Vienna Convention of 1968, which requires that there is a person on board the vehicle, the driver, to supervise entire driving task (Raptis, 2017, UNECE, 1968 et al.). Chosen solution on how to overcome this obstacle was to transfer driving “senses” to a remote location in real time, using IT methods. Driving senses refer to everything a driver can see and listen while performing driving task. These include view in front of, behind of, on the left of, on the right of and inside the vehicle, as well as to listen what is happening on board and outside the vehicle. Each vehicle would be monitored by a professional driver who would also be able to use the brake, when necessary (Raptis, 2017). Under those conditions, a Ministerial Decree (MD) that clarified legal status of AV and embedded them to Greek Highway Code (KOK) was prepared as following:

> *Operation of urban bus, without driver’s presence onboard (…) is allowed, only for research purposes in pilot application (Government Gazette of Greece nr. 1837B/26.08.2015, article 2, own translation from Greek).*

Demonstration, as any future related project, had to be approved by the Municipal Council, Decentralized Administration, local traffic police as well as to pass technical inspection. Moreover, permission will be issued for a specific time period and bus route; which have to be defined by an individual traffic plan (Government Gazette of Greece nr. 1837B/26.08.2015). Every following demonstration will have to be permitted in a new ministerial decree and follow above mentioned rules in order to be approved. Vehicles of the demonstration did not receive test but normal plates, so they were legally treated just as ordinary vehicles. Moreover, legal recognition of vehicles allowed them to be insured as ordinary ones at a common market price for a private car (Raptis, 2017, Vavitsas, 2017). Legal liability lies with remote operator, who must have a professional driving licence. Operator has to monitor vehicle’s movement at all the time and is responsible for only one vehicle at a time.

> *Vehicle operator: Person, placed at remote control centre, is responsible for vehicle's movement, is not present at the vehicle and is considered as its driver, according to the provisions of KOK (Government Gazette of Greece nr. 1837B/26.08.2015, own translation from Greek).*

Realization of the demonstration would not have happened without strong support by the ministry or without seamless cooperation with local authorities. Indeed, dealing with implementation and legal constraints was one of the most dominant aims of the entire CityMobil2 project and it was accomplished (City Mobil2, 2016b). Design and implementation processes passed through a considerable amount of "no" and the same as many "no, but"; the latter finally allowing the experiment to take shape. Dealing with all those responses successfully required much of persistence and of deep conviction that this project should be done for the city's good (Raptis, 2017).

5.2.3. From conception to completion

Planning and preparation of demonstration was not an easy task either. This involved necessary infrastructure for the buses to move and communicate with control centre as well as communication of the demonstration to local society and stakeholders (Raptis, 2017, Karaberi, 2017, Vavitsas, 2017).

> *Communicating to the people "why this project" was of critical importance, as we had to make clear why we take space out of a central part of the city and to ban all parking there for 6 months; finding a parking space in the city centre is very difficult (Karaberi, 2017).*

Communication strategy focused on the added value of the demonstration to the city, which included possibilities offered by ARTS to Trikala and increase in tourism attractiveness of the city (CityMobil2, 2016b). Promotion of the demonstration though should involve some other elements as well. For instance local music was being played during trips, while buses obtained names of great personalities, some of them come from the area).

Initially proposed bus route was different than the one finally chosen. However there was persistence in allocating the experiment in the city centre, in order for the demonstration to produce as valuable conclusions as possible (Raptis, 2017). Adding though such a new system to a city centre where parking demand far exceeds supply was a venture:

> *EU and coordinator of the project considered it as a miracle that we could make the project in the city centre. However, when they came to Trikala for the first area inspection they were shocked. In those 2,5 kilometers they confronted a state of anarchy. There were parked cars, trees, traffic lights and whatever else you can imagine (Raptis, 2017).*

Separation of bus lane from the rest of the road surface was also an issue that had to be solved. Greek legislation required that in order to take a bus land out of the street a 0,5 meters high concrete curb lane had to be built and lane had to be at least 2,5 meters wide. It was impossible though to extract 2,5 m out of the streets selected for the demonstration, as there would not be any more space for the rest of the traffic. On top of that, a 0,5 m. high separation barrier would be that high that the element of coexistence of the bus with ordinary vehicles would be by definition removed from the demonstration (Raptis, 2017). In addition to that, if separation barrier was more than 0,2 meter high it would be possibly recognized as a barrier by the bus; hence the bus would not move. Therefore, a couple of barriers already used in similar cases in other cities were not an option. Separation of bus lane took finally place using cat's eyes, which would also "intervene" into the existing visual and physical ambience of the street as little as possible (Raptis, 2017). Furthermore, since bus had to have absolute priority in intersections, conventional traffic lights had to be replaced by smart ones. Then, special parking spaces for impaired people and taxis should be relocated; while installation of new road signs across the city should take place.

Image 17: Cat's eyes

Source: CityMobil2 Research Unit, 2015

Image 18: Driverless bus and its lane

Source: Snoopit24.com, 2015

Next step was technical inspection of the vehicle. However, an important factor was missing from the equation. Buses did not have legal status of normal cars in previous demonstrations, so they had never passed ordinary technical inspection. Hence, technical requirements for their safe operation in mixed traffic (maximum braking distance etc.) were unknown. So, in order to for the buses to pass through that process as usual cars those specifications were defined from the beginning by the Institute of Communication and Computer Systems (ICSS) of National Technical University of Athens (NTUA) (Raptis, 2017, Vavitsas, 2017, Karaberi, 2017).

> *There are two kinds of infrastructure, namely what was required by the project (…) and what we did to get the demonstration one step ahead. (…) The idea was to make this route, this 2,5 km, as safe as possible and fast (Vavitsas, 2017).*

Another critical part of the demonstration was IT facilities, as they had to provide high-speed and seamless connection between vehicle, remote operator and smart traffic lights. In spite of the fact that such facilities are usually regarded as "soft" infrastructure, it could be argued that in that case they constituted the "hard" part instead. In specific, system was designed to feature extra high capacity and data transmission speed in order to ensure highest possible level of safety. This decision was also taken in order to promote project objective to establish, as mentioned before, "continuous cooperation (of the vehicle) with the infrastructure" (Vavitsas, 2017, CityMobil2, 2016b). IT infrastructure consisted of a fiber optic network (maximum speed 1 Gbp/s) with 30 Wifi access points, which were connecting the bus with control centre and traffic lights. In particular, the bus was in constant connection with an access point and the latter was transmitting information to the nearest traffic light and remote driver. Achieved transmission time was rather short, 0,1 ms, thus transferring driving senses to the driver and location data to traffic lights almost in real time (Raptis, 2017, Vavitsas, 2017, ICSS, 2015). Buses' equipment was enabling remote driver to do exactly what they would have been able to do if they were onboard. In particular there was an emergency brake, which could be used either by remote driver or onboard operator; Voice over Internet Protocol telephone, so that driver could talk with passengers and vice versa as well as smoke detector, which was connected with main switch of the vehicle and in case of fire it would stop it automatically. Utility of remote braking was not included in initial manufacturer's plans; though it was asked to be added by the implementing authority E-Trikala to minimize risks of the demonstration even further.

> *Two elements that made this demonstration to stand out: First the total length of the route was in an entirely urban environment, where grandpas, children, people on wheelchairs, cars, buses and motorcycles were moving altogether. Second, it was our interventions in the experiment, namely the coverage of the whole part of the area with fiber optics, wifi and a vast amount of cameras in order to have the driver out of the vehicle (Vavitsas, 2017).*

Buses' logic is to prevent any kind of accident in any possible way. When facing any object that might be just close to its route, bus was gradually decreasing its speed from its operational one 16 km/h to even 1 km/h (!) in order to be fully sure way is clear. In case somebody or something was laterally approaching it at a distance of less than 20 cm bus automatically stopped. However, demonstration intended at showing driverless mobilities are feasible, not at optimizing them:

> *Then you will ask me; with all those pieces of safety equipment how slow it will drive? At 5, at 10 or at 15 km/h? An EU commissioner (...) told me "We are waiting for Trikala to answer the following: can it (driverless bus) drive at an average speed higher of the walking one?". And we proved that it can (Raptis, 2017).*

Image 19: First test of driverless bus in Trikala streets

Source: E-Trikala SA, 2015

Preparing for an event/project etc. can be hard; though executing the project itself is much harder. Trikala demonstration was characterized by great success but also confronted problems.

> *We were beginning at 1 October. At 31st of September in the evening, I did the route in order to see if all details were ok. I was shocked! The street was full of (illegally parked) cars! I thought "oh my god, it will be a catastrophe". Next day at 9.00 there was not a single vehicle on the bus lane (Raptis, 2017).*

Achievements include realization of 4030 kilometers in 1490 routes and transportation of 12138 people in total at 8,15 users per route on average (75% occupancy rate) (Karaberi, 2016). Bus ran autonomously in the designated route without intervention from the operator at any time in the demonstration. Vehicle flexibility to move elsewhere than its specified axis of movement was not the point of the demonstration and therefore was not available:

> *If you ask me if these buses can be released to the streets the answer is no. In an area where it is more – politically - feasible to take a lane out of the road to give priority to sustainable mobility modes you could have a vehicle like this, but it will have no difference with a tram (Raptis, 2017).*

Image 20: Students get onboard the driverless bus

Source: Video screenshot of CityMobil2, 2016c

People not only saw driverless technologies in practice but also came closer with the concept of sustainable urban mobilities (Karaberi, 2016). Demonstration added to the already gained reputation of Trikala as innovative city, while it provided city with invaluable publicity both domestically and abroad. Publicity had to do with three matters; namely how it became legally feasible to introduce ARTS in public streets; how such close and seamless cooperation between all national and local stakeholders was achieved; and how it happened for such an experiment to be successful in a city where car traffic extracts an important part of urban space (Raptis, 2017, Karaberi, 2017, Vavitsas, 2017).

> *The most important for me was that people saw for first time the city centre without parked and double-parked cars everywhere; also being more pedestrian- and cyclist-friendly (Karaberi, 2017).*

This publicity, apart from improving the image of the city had a noticeable contribution to people's pride. The reason is that success of the demonstration did not happen only through aforementioned innovations "from above", namely from local and national stakeholders; but it was also because people embraced and supported that. People, including passengers of the bus and users of the street in general (drivers, cyclists, pedestrians), respected both the bus itself and its movement.

> *City completely respected bus' movement. It's a city where you can't find a single parking space but still it respected the bus (Raptis, 2017).*

Incidents with parked cars on the bus lane were very few and were mostly done either by people from other areas, who might be not aware of the demonstration; or by opponents (political etc.) of the demonstration in order to intentionally obstruct bus' movement. Such incidents also took place at the very beginning of the project, as pretesting began in August, when a part of the population might not be in the city.

Date of the experiment was also a part of this success. Project took place along with the local Christmas festival "Mill of the Elves", which attracts visitors from all over the country (Hellenic Broadcasting Corporation website, 2016). This event was launched in 2011 and takes place for around 40 days each year (Mylosxotikon – "Mil of the Elves" website, 2017). In 2015 it took place between 27/11/2015 and 3/1/2016 (Trikala Day website, 2015b), therefore visitors of the event has also the opportunity to use the driverless bus. It can be assumed that this also contributed to the success of the experiment, particularly in terms of the publicity it gained in other areas of Greece.

Negative propaganda by opposing parties is regarded by Raptis (2017) as the most important problem during the demonstration. Some publications headlines of the beginning period, describing the bus, are "Kick out satanic robot" (protothema.gr, 2015) and "The "Headless monster", which terrorizes citizens", (crashonline.gr, 2015a). Press also named it "gavo", which refers to somebody/something that moves without looking ahead. Negativism gained even more ground at a time when at 26th November, in spite of the dense network of wifi access points, bus once lost its connection with the satellite. This is attributed to the fact that in urban environment a huge number of obstacles may intervene between an object and the satellite, as well as it might also happen due to unexpected circumstances, such as operation of Very High Frequency (VHF)/Ultra High Frequency (UHF) transmitters etc.. When bus lost connection, it started moving out of its way to the right and stopped automatically, after it exceeded lateral safety limit of 10 cm. Bus was also equipped with obstacle detection sensors, so in case a pedestrian or an obstacle was on its way it would have stopped even earlier.

Image 21: Incident where the bus deviated from its way

Source: Zougla.gr, 2015

In spite of the particularly immediate response of the bus' electronics as well as of the rather low speed bus was driving at, overreaction was not avoided (Raptis, 2017). Overreaction, which is rather expected in such cases (Kyed, 2017a), was mainly facilitated by local press and other stakeholders who were opposing demonstration from the beginning (Raptis, 2017). Some of the publications headlines were: "Trikala driverless bus got crazy: It mounted the pavement and ran over a kiosk" (Trikala Day website, 2015a); "Trikala driverless bus crashed! Autopilot lost control!" (Crashonline.gr, 2015b); "Trikala driverless bus crashed!" (Iefimerida.gr, 2015). Incident had also a legal dimension, as a group of people sued E-

Trikala SA and Municipality for the "threats" this demonstration is posing for the city (Trikalaview.gr, 2015), eventually without legal consequences for the authorities. Communication of the incident focused on the existence of a wide range of safety systems as well as on their readiness, while it included a video where a member of E-Trikala runs in front of a driverless bus for quite many times and bus detects him instantly at all of them [Trikalaola.gr, 2015 (video, from 6.30)]

> *So what does technology teach us? In spite of any imperfections it has, safety features it carries continue working (Raptis, 2017).*

5.2.4. Assessment by public and stakeholders

Gaining insight on how passengers, citizens and local stakeholders evaluated both the demonstration and ARTS themselves was a critical component of the project. Toolbox for that involved a ex-post satisfaction survey of passengers of the bus (200 participants); ex-ante and ex-post Stated Preference (SP) surveys of ARTS passengers (208 participants in ex-ante and 200 in ex-post survey); a wider public survey (600 participants) and a stakeholders' survey (12 participants from public authorities, urban planning authorities, passenger transport operators, university experts and freight operators). Attitudes towards both demonstration and driverless mobilities in general were positive across all population cohorts (Karaberi, 2016, 2017, CityMobil2, 2016a). As expected, since route was designed in order to serve primarily demonstration purposes, vast majority of passengers (87,5%) used ARTS for recreation/shopping purposes or just to travel on ARTS. Awareness about demonstration was raised mainly from TV (83%), internet (59%) and radio (52%) (multiple sources could be chosen). Overall passenger satisfaction was rated as high 3,8 on a scale from 1 to 5 and consisted of 7 parameters; namely usefulness, integration with other modes, level of service, frequency of decelerations, comfort, jerk and information provision (Karaberi, 2016, 2017, CityMobil2, 2016a,). Ex-ante and ex-post SP surveys highlighted that existence of onboard staff did influence sense of safety on ARTS notably; though 29% of respondents would be more willing to use ARTS if there is somebody present at the vehicle. Willingness to pay more for ARTS over ordinary PT was evident in around 1/3 of sample, even though 54% of them would not be attracted if price of ARTS was higher. Passengers' opinion was improved significantly after having experienced ARTS, while the vast majority of them were in favor of implementing driverless mobilities in the city permanently but not in the same route.

Perceptions towards that were positively correlated with level of education, namely the higher the education level the more positive the attitude towards ARTS (CityMobil2, 2016a). Acceptance of ARTS by wider public was also high, however only 20% of respondents considered them as safer than human drivers. Main reason for preferring them over conventional PT or taxis would be the lower fare and the possibility for mobility from A to B without changing means. Most important benefits of ARTS were the potential to offer "mobility for all" and the possibility to do other things while driving; while most common drawbacks were "higher vehicle purchasing cost", "legal liability in case of an accident" and "risk of vehicle security (from hackers)" (Karaberi, 2016, 2017, CityMobil2, 2016a). Local stakeholders also adopted supportive attitude towards ARTS. They expressed their preference in operating ARTS in a shared manner as well as they stated this form of mobilities can have a positive impact on safety, environment, comfort, convenience, transport efficiency and economic aspects. Moreover, they highlighted importance of institutional and organizational matters, such as "commitment of key actors" and "existence of a sustainable development agenda" in implementing this kind of mobilities (CityMobil2, 2016a).

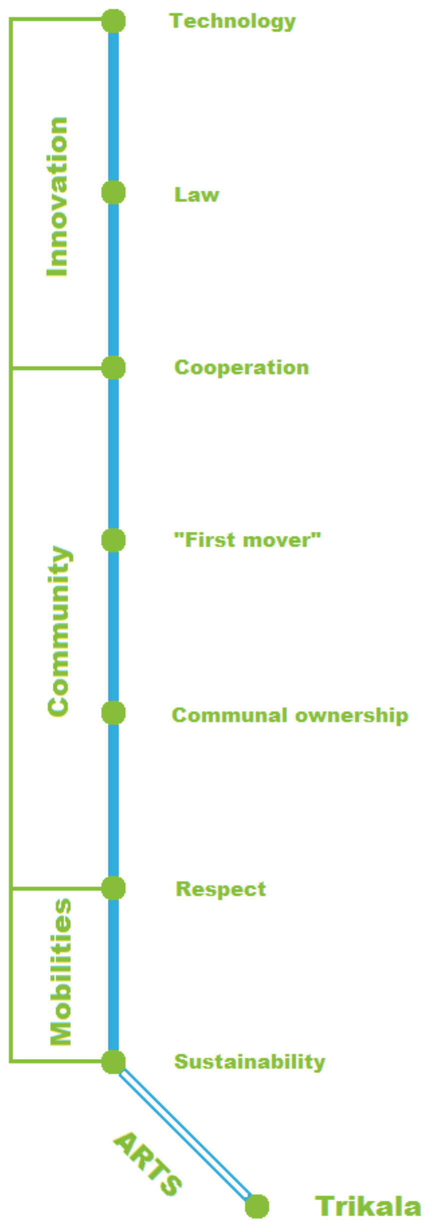
5.2.5. "After the (driverless) car"

Demonstration provided city of Trikala with plenty of material and knowledge infrastructure. One of those elements is the former bus lane in the centre, which was converted into a bike lane, thus enriching cycling infrastructure of the city. Moreover, the possibility for the city to use driverless technology in the future was assessed. For that reason a scenario was created, where car traffic in the city centre is drastically reduced - or even banned -, and trips to or from it are made by driverless buses. In particular four Park and Ride points in the outskirts of the city were created, two of them serving main transportation hubs, namely railway station and city's bus terminal. Cost-benefit analysis, examining feasibility of the scenario, by estimating reduction of accidents, travel time and emissions showed a clearly positive Benefit-Cost Ratio (BCR) of 2,1. It is particularly positive that result is that encouraging, even without including non-quantifiable benefits, such as shift of parking land usage from cars to people, increase in tourism, indirect health effects (less noise pollution etc.) and so forth. Another part of the "heritage" demonstration left behind was that the high-capacity wifi and fiber optic networks supplemented the existing municipal broadband internet network, providing an ever better service to citizens and visitors of the city. On top of the above, knowledge gained by demonstration will be a valuable tool for participating in CityMobil4 programme,

Image 22: Former bus lane turned into a bike one

Source: Personal archive

Figure 14: Elements of ARTS demonstration in Trikala



Source: Own editing

Above figure (14) illustrates main components of ARTS demonstration in Trikala. Its designed is based on the major objective of ARTS, which is to constitute a solution for the last mile problem. Beginning from the field of innovation, as expected, basis of the experiment is technology. Urban environments are highly demanding from many perspectives (many kinds of traffic, unexpected movements, unstable satellite connection etc.), so existence of ample and interchangeable safety systems is necessary. Legal innovation was an irreplaceable part of the demonstration, as this was the basis for its implementation, at least in mixed traffic. Moreover cooperation between implementing company E-Trikala, national and local stakeholders proved to be essential for legal, institutional and practical barriers to be overcome. A particularly encouraging point is that demonstration was greatly supported by local community. The reason is it had an unforeseen contribution to city's reputation as "first mover", thus making them to acknowledge its benefits for their city, such as increase in tourism, in spite of the crisis and enhanced business attraction. Along with that, by incorporating many local elements in the experiment, such as playing local music onboard or giving names of local artists to buses, people were encouraged to see the experiment as "communal ownership". Then, positive attitude towards demonstration had a decisive effect on its success, as overwhelming majority of road users fully respected bus' movement, thus proving driverless technology can offer a lot, even in dense car traffic. Another contribution of the demonstration to the city is that people saw in practice that adopting a more sustainable approach in mobilities neither will put barriers on their everyday life nor is practically (or politically) inapplicable. For the above reason a wide part of the population were happy with both keeping driverless buses after the experiment and with making city centre more car-free.

5.2.6. Epilogue

ARTS demonstration in Trikala could be characterized as one of the first decisive steps towards realization of driverless mobilities in public streets. For its implementation, a wide range of institutional, political and practical obstacles should be overcome. These were the lack of corresponding legal framework, first-mover risk and complexity of urban traffic. Therefore, strong political willingness and close collaboration between relevant stakeholders were necessary. Another factor influencing success of the demonstration was that city had already been a test bed for technological innovations - also adopting permanently many of them –, therefore it can be assumed that society was rather familiar with testing and adopting new technologies. Communication of the demonstration was also of critical importance, as it provided information to the public about how ARTS work and how they will be incorporated into existing everyday practices, thus building transparency about the experiment. In parallel, awareness-raising campaigns also highlighted the community-oriented character of the demonstration, thus raising the feeling "this is ours", which was translated into high acceptance and full respect of the bus. On top of that, it can be assumed that increased touristic attractiveness, caused by the Christmas event further contributed to the success of the driverless bus project. This is because it can be expected that an amount of visitors of the Christmas event made use of the driverless bus too, while they also communicated the project and their experiences to other parts of Greece; thus bringing valuable publicity. Finally, high actual and perceived safety was a core component of demonstration's success, as it both created trust among the public and probability of failure was minimized. As a result of the above, paraphrasing Dennis and Urry (2009) it could be argued that demonstration in Trikala showed there are good outcomes after the driverless car. Moreover, also opposite to what Dennis and Urry (2009) support about the ordinary car: It (ARTS) and its low carbon friends would seem to have done their best to leave much of what we need to make mobilities sustainable and more of a common good than they are today even as it itself disappeared from view.

Above chapters depicted how driverless mobilities work both theoretically and practically. Examined cases provided an empirical foundation to elaborate on benefits, concerns and implementation process of driverless mobilities. In the section below, similarities and differences of those cases are unfolded, so that conditions under which findings can be transferred to other cases are made clear.

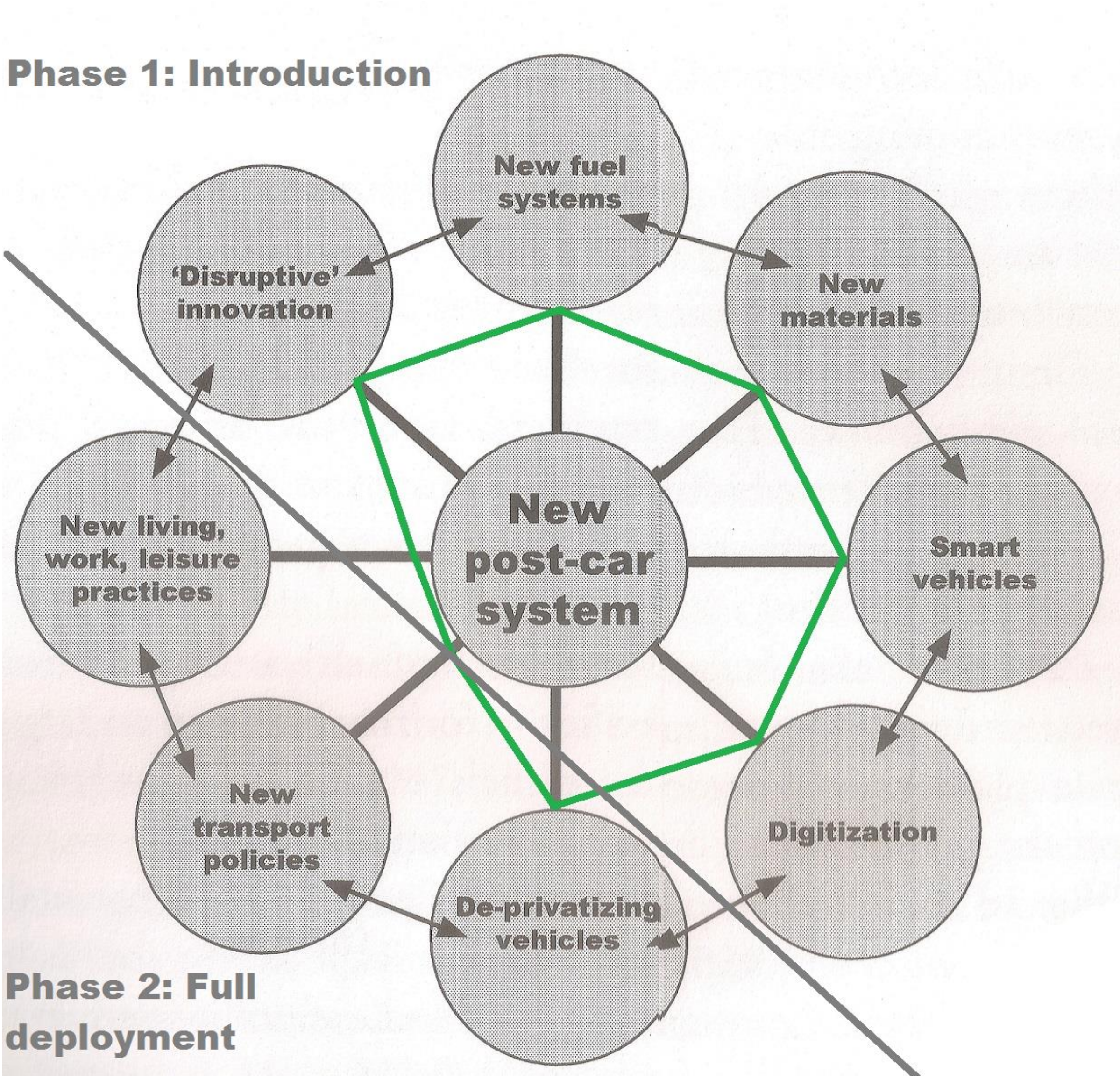
5.3.Cross-case analysis

This chapter featured a study of two outstanding cases where driverless mobilities are materialized. Since these cases are considered as forerunners in the establishment of this new form of mobilities, they are used as means to specify how far the implementation of driverless mobilities has progressed in general. Moreover it is intended to identify which are the challenges and the opportunities the introduction of this new mobilities system faces in practice.

Studied cases refer to use of level four electric driverless buses in urban environments. AV operate in public service, while Aalborg project may also offer demand-responsive service in the future. Buses operate in specified route in mixed traffic either with all types of vehicles or with bikes. Rolling out the bus in mixed traffic is ambitious in both cases, because environments where buses ran/will run are rather demanding for various reasons. In Aalborg, buses will perform regular PT service as well as move together and coordinate with cyclists in public street, in the first experiment of this kind. At the same time, Trikala experiment faced the threat of having illegally parked cars on the bus lane, which could make the whole experiment collapse. The chances of this catastrophic potential were considerable, as bus lane was located in the city centre where availability of parking spaces is limited. That could be translated to the fact that buses' movement in both cases depends on priority they gain from other users of the road. In line with that, potential failure in Trikala demonstration would pose many concerns. Such a case would be an indication that in spite of the numerous environmental, spatial etc. threats car dominance brings, societies might not be willing even to try to overcome it. Respectively in Aalborg, if cyclists do not give priority to the bus, its speed will be rather low, thus preventing the service from fulfilling its purposes; namely to provide mobility for all and to be a means of social inclusion in Aalborg East. Among other similarities, one of the core objectives of both projects is the improvement of city's image in the direction of "first mover". Both cities constantly prove their capability in engaging successfully with disruptive innovation and new technologies; and these projects constitute a valuable opportunity for them to take a step forward to the future. The venture is a tall order, as they have to persuade their people to not only to overcome the perceived cost of the lack of driver in a vehicle they share their road with, but also to trust this vehicle for the transportation of themselves, of their children etc.. As seen in Trikala, achieving the above mentioned target will not only open up new horizons for the transformation of these cities into smart ones but also contribute to the further development and diffusion of driverless technology in general. Innovation is not only practical but also legislative, as both cities are the first to make use of national legislation framework allowing driverless vehicles in public streets for research purposes (Aalborg does so together with Vesthimmerland Municipality). At the same time, they both try to prove that driverless buses are safe enough to run in mixed traffic, so they should be further allowed to operate in public streets.

Taking as point of departure the analysis of Dennis and Urry (2009) and the categorization of elements of the post-car system (see chapter 3), a wide spectrum of elements of the post-car system are embedded in those projects. These are "disruptive" innovation, new system fuels, new materials, smart vehicles and digitization, which belong to phase 1 (Introduction of the post-car system) and the de-privatization of vehicles, which falls under phase 2 (Full deployment of the post-car system). Driverless technology exists at a laboratory level but is rather immature to get out in the streets. Therefore both projects focus on the successful accomplishment of phase 1, namely to "teach" the technology how to coexist and interact with human-powered mobilities. At the same time, it is endeavored for these projects to provide the local societies with the “brand name” of “first mover” and new mobilities services. This way AV both enhance local mobilities and widen development prospects of those areas in general. On top of that both AV services operate as PT, thus showing the importance of de-privatizing mobilities in establishing a sustainable next-day mobilities system. Studied projects do not elaborate much on the possibility of new transport policies or living, work and leisure patterns. This is because these aims will come later on the forefront, when driverless technology will have more largely been developed and practiced.

Figure 15: Elements of the post-car system, which are embedded into the examined cases



Source: Own edit on Dennis and Urry, 2009 p. 64.

It could be argued that one of the most critical factors of success of such projects is the existence of fertile ground. This refers to an environment where the technology can prove in practice its usefulness and comparative advantages as well as where these attributes can be widely acknowledged by the society. In the examined cases for instance, Aalborg East is considered as a more fertile ground than Aalborg West, as higher car ownership levels in the latter may limit usefulness of PT, regardless if it is driverless or not. At the same time, Trikala was more suitable than other Greek cities in accommodating this demonstration due to city's experience as an innovation test-bed and tradition in dealing with smart technologies. Another outcome of the cases examination is that support from national and local authorities, as well as collaboration between relevant stakeholders are determinant in order for technological innovations to be embedded into everyday practices. Reasons for that can be first-mover risk, legal barriers, bureaucracy, practicalities and institutional issues. From the legal perspective, importance of political willingness was more evident in Trikala because law was not preexisting but was prepared on purpose in order this demonstration to be feasible. Communication also proved to be highly important in both cases, as it raised public awareness about the projects and cultivated a sense of communal ownership towards them.

6. CONCLUSIONS

Scope of the project is to shed light on how driverless mobilities are shaped, which will be their modus operandi as well as how and when they will be implemented. In the first two chapters of the project it is endeavored to provide a definition of this form of mobilities and an understanding of its parameters. Then in the second part driverless mobilities are examined as regards their benefits, the concerns their materialization brings, the acceptance they will gain by society as well as concerning legal and ethical issues of their realization. In the third part, one of the first cases where AV will perform regular mobilities service, in Aalborg East, Denmark, was investigated in order to identify its logic as well as the driving forces behind its materialization. Afterwards in this section, research upon the first time ARTS were rolled out onto public streets, in Trikala, Greece, took place, in order to find out about its objectives as well as difficulties its implementation faced. First part of the conclusions embeds an illustration of driving forces behind the implementation of this new mobilities system. Then in the second part, duration and aspects of the transition phase towards the fully driverless era is being discussed, according to two scenarios on how driverless mobilities will be eventually formed.

One of the driving forces, supporting this form of mobilities is that society seems to be willing to experiment with and gain richer knowledge on this technology. Further progress at a regulatory level, which will enable an increase in AV applications as well as raised awareness on their modus operandi and usefulness, can pave the road for wider diffusion of this innovation. Review of Aalborg and Trikala cases as well as of existing scientific evidence highlighted legal and institutional matters in making driverless mobilities, particularly in mixed traffic, as a notable challenge. Liability and ethical issues will also influence acceptance and adoption rate of AV, but they are still largely undefined. Study of Aalborg and Trikala cases highlighted safety, proof of usefulness and people’s perception of AV as the most critical factors in the successful implementation of driverless mobilities. Therefore, in order for people to trust AV as a means of mobilities and a part of their environment particular effort has to be made in order to minimize any safety risk regarding vehicle’s equipment and possible presence of other kind of traffic. Moreover, AV, should be deployed in services that highlight the possibilities of this technology, such as flexibility, lower operational cost and smart technology by filling in the gaps of the existing mobilities system of each area. This is because it will be rather difficult for people to remove human factor from their minds if no particular advantages occur, such as lower fares or less waiting times. On top of that, perception of society towards driverless mobilities will largely affect their realization and diffusion, hence their modus operandi and benefits should be extensively communicated. At the same time AV should embody no less qualities than ordinary cars (modernity, comfort, entertainment equipment etc.) but even fill their gaps, e.g. by replacing philosophy of sedentarism with sense of community. An outcome of the case examination is that initiatives where shared AV are rolled out onto the streets can greatly strengthen sense of community in the area, as citizens may treat these projects as communal ownership. Therefore, extensive communication of this advantage may generate interest from public authorities/companies/universities etc. to introduce or test driverless mobilities at smaller (inside campuses) or larger (for the last mile problem) scale. Analysis also showed that fully unmanned operation is less of a challenge in gaining acceptance of driverless mobilities, as it is becoming increasingly evident that onboard operators perform more a psychological than an actual role.

> *If we look into a scenario with AV, the distinction between a car where people are driving together and a public bus will not be that important (Egense, 2017).*

Diffusion of driverless mobilities is still at an early stage, hence their final modus operandi is hard to be predicted. In this project it is speculated that the fully driverless era will become a reality in 2035-2040. However, as discussed in this project, during this transition, mobilities system will be affected in many ways, such as concerning the demand and supply management; the ownership structure of vehicles; or the scales of the forms of mobilities e.g. by adding “Hybrids” like in Aalborg East. For that reason, examination of how AV will shape future mobilities will take place through the creation of two scenarios. First scenario elaborates on small capacity AV (up to 10-12 seats), like the ones used in the two examined cases, which supplement (in the future driverless) PT in low demand routes, where keeping regular bus lines is not economically feasible. Lower operating costs, caused by the use of electricity instead of gas and the lack of driver’s wage; will allow increased frequency, lower fares and possibly establishment of DRT service, thus making it more able to compete with private car. Second scenario elaborates on a situation where in a few decades point-to-point driverless mobilities will become the only means of getting around. This will pose some remarkable benefits, such as drastically less traffic accidents, more point-to-point mobilities options as well as change entirely the way we perceive private car today, by making it more similar to computers than to cars actually. On the other hand, since exact conditions of such a situation have not been defined yet, many questions regarding safety, security pricing, liability and ethics in the era of those "cars" remain to be answered. As stated above, only practical difference in these scenarios is the notion of PT. In the first scenario AV just supplement arterial PT networks, while in the second one small driverless pods are the only form of driving object on the street. It would be hard to provide a reliable speculation on which scenario will finally become a reality, as logic and parameters of driverless mobilities are still far from given. The only sure is that network capacity parameter will be difficult to be overcome. In other words, it will be rather unexpected that everybody will be able to access high congestion corridors or areas, like city centres, on a small pod, even if this is shared with three or four more people. Contrariwise, in areas where congestion is low it could be assumed there will be no reason to keep medium-sized buses, whose occupancy rates will not even be satisfactory, when there is enough road capacity for a dense network of DRT. At the same time, all these scenarios and statements do not take into account any possible new form, or even new scale, of mobilities, which may not only challenge notion of PT but also concept of driverless car we have just seen.

7. PERSPECTIVES FOR FURTHER RESEARCH

This projects endeavors to depict modus operandi of driverless mobilities, as well as how and when they will be materialized. In line with the analysis of Dennis and Urry (2009) and the categorization of the elements of driverless mobilities illustrated in above sections, from a mobilities planner's point of view, further research should shed light on the elements of phase two (full deployment of driverless mobilities. In specific, it should be examined which new transport policies could (or should) be applied, how de-privatization of mobilities can take place as well as how new living, work and leisure practices can be established. This is because technology is already there, it is currently being set into practice and what should be investigated at the moment is to find out how it should be realized in order for the benefits of this new form of mobilities to be maximized. On this basis, two ideas on which could be the examined objects in the future research projects are following. First, it would be interesting to examine the contribution of neighborhood-scale AV routes in spatial and social cohesion in the served area. This example could refer to the case of Aalborg East, where AV will connect various parts of the neighborhood with local centre and other facilities. In such a case many issues could be researched, to mention a few ex-ante and ex-post acceptance of the new mode; the extent new mode enhanced attractiveness of local centres/facilities to local people; and contribution of new mode to social cohesion. Second, it could be worth examining which are the criteria for characterizing an area as "fertile ground" for introducing driverless mobilities. For instance, in the case of Aalborg one of those conditions is the existence of people who might be not so mobile; hence driverless mobilities will provide them with a possibility they did not have before. Therefore, they have a strong incentive to "make the concession" to try a non-driver experience, therefore possibly acknowledge advantages of this innovation. As highlighted in the analysis of the second case, Trikala, fertile ground was not created by the lack of a particular mobilities service, but by the experience of the city in innovating, which had made people more willing to experiment on new technologies.

8. BIBLIOGRAPHY

Aalborg Municipality (2012): "Northern Denmark's Growth Dynamo (Norddanmarks vækstdynamo)" [In Danish]. [online] Available at http://www.e-pages.dk/aalborgkommune/401/html5/ . Accessed 11/6/2017.

Aalborg Municipality (2013): "Spatial Vision 2025 (Fysisk Vision 2025)" [In Danish]. [online] Available at http://www.e-pages.dk/aalborgkommune/690/html5/ . Accessed 14/5/2017.

Alessandrini, A., Alfonsi, R., Delle Site, P., Stam, D. (2014): "Users' Preferences towards Automated Road Public Transport: Results from European Surveys", *Transportation Research Procedia*, 3, Elsevier. pp. 139-144. [online] Available at https://doi.org/10.1016/j.trpro.2014.10.099 . Accessed 3/4/2017.

Alessandrini, A., Campagna, A., Delle Site, P., Filippi, F., Persia, L., (2015a): "Automated Vehicles and the Rethinking of Mobility and Cities" (SIDT Scientific Seminar 2013), *Transportation Research Procedia*, vol. 5, Elsevier, pp. 145-160. [online] Available online at https://doi.org/10.1016/j.trpro.2015.01.002 . Accessed 6/6/2017.

Alessandrini, A., Delle Site, P., Gatta, V., Marcucci, E., Zhang, Q. (2015b): "Stated Preference Logit Analysis of Users' Attitudes Towards Conventional and Automated Buses", *CREI Working Paper*. No. 2. [online] Available at: http://host.uniroma3.it/centri/crei/pubblicazioni/workingpapers2015/CREI_02_2015.pdf. Accessed 12/3/2017

Alonso-Mora, J., Samaranayake, S., Wallar, A., Frazzoli, E. and Rus, D. (2016): "On-demand High-capacity Ride-sharing via Dynamic Trip-Vehicle Assignment", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 114, No.3, pp. 462-467, November. Available at http://www.pnas.org/content/114/3/462.full.pdf. Accessed 3/4/2017.

Bansal, P., Kockelman, K. M. (2017): "Forecasting Americans' Long-term Adoption of Connected and Autonomous Vehicle Technologies", *Transportation Research Part A* 95, Elsevier, pp. 49-63. [online] Available at: http://dx.doi.org/10.1016/j.tra.2016.10.013 . Accessed 12/6/2017.

Bazilinskyy, P., Kyriakidis, M., de Winter, J. (2015): "An international crowdsourcing study into people's statements on fully automated driving", *Procedia Manufacturing*. 3, Elsevier, pp. 2534-2542. [online] Available at https://doi.org/10.1016/j.promfg.2015.07.540 . Accessed on 2/4/2017.

Beiker, S. A. (2012): "Legal Aspects of Autonomous Driving", *Santa Clara Law Review*. 52:4, pp. 1145-1156. [online] Available at http://digitalcommons.law.scu.edu/cgi/viewcontent.cgi?article=2726&context=lawreview . Accessed 5/5/2017.

Bill (Lovforslag) nr. L 120, series (Folketingettidende) A of 25.1.2017 on "Act amending the Highway Code (Authorization to lay down rules for and authorize tests for self-propelled vehicles) [Lov om ændring af færdselsloven (Bemyndigelse til at fastsætte regler om og give tilladelse til forsøg med selvkørende motorkøretøjer)]" [In Danish]. [online] Available at http://www.ft.dk/RIpdf/samling/20161/lovforslag/L120/20161_L120_som_fremsat.pdf . Accessed 26/7/2017.

Cervero, R., Murphy, S., Ferrell, C., Goguts, N., Tsai, Y-H., Arrington, G.B., Boroski, J., Smith-Heimer, J., Golem, R., Peninger, P., Nakajima, E., Chui, E., Dunphy, R., Myers, M., & McKay, S. (2004): "Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects". *Transit Cooperative Research Program (TCRP) Report 102*, Transportation Research Board, Washington. [online] Available at http://www.valleymetro.org/images/uploads/general_publications/TCRP-Report-102_TOD-in-the-US-Experiences-Challenges-and-Prospects_10-04.pdf . Accessed 12/4/2017.

Chen, Z., He, F., Yin, Y., Du, Y. (2017): "Optimal design of autonomous vehicle zones in transportation networks", *Transportation Research Part B 99*, Elsevier, pp. 44-61. [online] Available at: http://dx.doi.org/10.1016/j.trb.2016.12.021. Accessed on 13/3/2017.

Chittilla, H. and Sun, D. (2017): "Self-driving Cars". *Department of Computer Science, University of North Carolina.* [online] Available at http://www.cs.unc.edu/~lin/COMP089H/LEC/SelfDriveCars.pdf. Accessed 5/3/2017.

Choi, J. K., Ji, Y. G. (2015): "Investigating the Importance of Trust on Adopting an Autonomous Vehicle", *International Journal of Human–Computer Interaction*, vol. 31, issue

10, Taylor and Francis, pp. 692-702. [online] Available at: http://dx.doi.org/10.1080/10447318.2015.1070549. Accessed 2/7/2017.

Christie, D., Koymans, A., Chanard, T., Lasgouttes, J.-M., Kaufmann, V. (2016): "Pioneering driverless electric vehicles in Europe: the City Automated Transport System (CATS)", *Transportation Research Procedia*. 13, Elsevier, pp. 30-39. [online] Available at https://doi.org/10.1016/j.trpro.2016.05.004 . Accessed 4/6/2017.

CityMobil2 (2013): "Legal Issues and Certification of the Fully Automated Vehicles: Best Practices and Lessons Learned". [online] Available at http://www.citymobil2.eu/en/upload/Deliverables/PU/CM2-D26.1.pdf . Accessed 14/7/2017.

CityMobil2 (2016a): "Trikala Ex-post Evaluation Report". WP.25, D25.4, Seventh Framework Programme. *Institute of Communication and Computer Systems; E-Trikala S.A.; TRG, Southampton University; CTL, Universita Degli Studi di Roma La Sapienza; Istituto di Studi per L'Integrazione dei Sistemi SCRL.*

CityMobil2 (2016b): "Experience and Recommendations". [online] Available at http://www.citymobil2.eu/en/upload/Deliverables/PU/CityMobil2%20booklet%20web%20final_17%2011%202016.pdf . Accessed 14/7/2017.

CityMobil2 Research Unit (2015): Traffic Management Plan for Trikala Demonstration of CityMobil2 Research Project (Έκθεση Διαχείρισης της Κυκλοφορίας στα Πλαίσια του Ερευνητικού Προγράμματος CityMobil2) [In Greek]. Second Review, 4/9/2015.

Collingwood, L. (2017): "Privacy implications and liability issues of autonomous vehicles", *Information & Communications Technology Law*, vol.26, issue 1, Taylor and Francis, pp. 32-45. [online] Available at: http://dx.doi.org/10.1080/13600834.2017.1269871. Accessed 19/6/2017.

Council of the European Union (2016): "Stimulating the Uptake of Space Data". Content Collected by Countries' Delegates for the Competitiveness Council on 26 May 2016. *Netherlands Presidency of the Council of the EU*. [online] Available at http://www.citymobil2.eu/en/upload/public-docs/160526%20Booklet%20Stimulating%20the%20uptake%20of%20space%20data-_European%20examples%20%20%20%20.pdf . Accessed 7/6/2017.

Dennis, K. and Urry, J. (2009): *After the Car*. Cambridge: Polity

E-Trikala S.A. (2015): Photos of CityMobil2 Demonstration

E-Trikala S.A. (2017): "E-Trikala S.A. Profile". [online] Available at http://www.e-trikala.gr/wp-content/uploads/2013/01/Profile-e-trikala-ENG.pdf. Accessed 17/6/2017.

European Commission (2012): "Public Attitudes Towards Robots". Special Eurobarometer 382. [online] Available at http://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_382_en.pdf. Accessed 12/4/2017.

European Road Transport Research Advisory Council (2015): "Automated Vehicles in the EU". [online] Available at http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573902/EPRS_BRI(2016)573902_EN.pdf . Accessed 5/7/2017.

Fagnant, D. J., Kockelman, K. (2015): "Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations", Transportation Research Part A 77, Elsevier,, pp. 167–181. [online] Available at: http://dx.doi.org/10.1016/j.tra.2015.04.003. Accessed 9/3/2017.

Flyvbjerg, B., 2004 in Seale, C., Gobo, G., Gubrium, J.F. and Silverman, D. (eds.), (2004): "Five Misunderstandings about Case-study Research", *Qualitative Research Practice*, pp. 420-434. London and Thousand Oaks, CA: Sage. [online] Available at http://flyvbjerg.plan.aau.dk/MSFiveMis9.0SageASPUBL.pdf. Accessed 29/5/2017.

Frisoni, R., Dall'Oglio, A., Nelson, C., Long, J., Vollath, C., Ranghetti, D., McMinimy, S. (2016): "Research for TRAN Committee – Self-piloted Cars: The Future of Road Transport". *European Parliament Committee on Transport and Tourism*. [online] Available at http://www.europarl.europa.eu/RegData/etudes/STUD/2016/573434/IPOL_STU(2016)573434_EN.pdf . Accessed 2/7/2017.

Geddes, N. B. (1940): *Magic Motorways*. New York: Random House. [online] Available at https://archive.org/details/magicmotorways00geddrich. Accessed on 8/7/2017.

Gold, C., Körber, M., Hohenberger, C., Lechner, D., Bengler, K. (2015): "Trust in automation – Before and after the experience of take-over scenarios in a highly automated vehicle", *Procedia Manufacturing*. 3, Elsevier, pp. 3025-3032. [online] Available at https://doi.org/10.1016/j.promfg.2015.07.847. Accessed on 3/5/2017.

Goodall, N. J (2014): “Ethical Decision Making During Automated Vehicle Crashes”, *Transportation Research Record: Journal of the Transportation Research Board*, No. 2424, pp. 58-65. [online] Available at: http://dx.doi.org/10.3141/2424-07. Accessed 19/6/2017.

Government Gazette of Greece, 1837, series B of 26/08/2015. Athens: National Printing House. [online] Available at http://www.et.gr/idocs-nph/search/pdfViewerForm.html?args=5C7QrtC22wE4q6ggiv8WTXdtvSoClrL8t3VVDiksYNv3U4LPcASlceJInJ48_97uHrMts-zFzeyCiBSQOpYnTy36MacmUFCx2ppFvBej56Mmc8Qdb8ZfRJqZnsIAdk8Lv_e6czmhEembNmZCMxLMtaOuOLO1aNbsT1bZXI8nKHp0cox8EeW1MCo-AlXqO8Ab. Accessed 18/6/2017.

Greek Ministry of Interior, Decentralization and Electronic Governance (Υπουργείο Εσωτερικών, Αποκέντρωσης και Ηλεκτρονικής Διακυβέρνησης) (2010): “Everyday Life of a Family in a “Digital City”, year 2015 (Η Καθημερινότητα μιας Οικογένειας που Ζει σε μια Ψηφιακή Πόλη, Έτος 2015)” [In Greek]. [online] Available at https://www.google.gr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiajILp7Y3VAhUL1hQKHfEVCYsQFgglMAA&url=http%3A%2F%2Fwww.ypes.gr%2FUserFiles%2Ff0ff9297-f516-40ff-a70e-eca84e2ec9b9%2Fpsifiakos_dimos_2014.doc&usg=AFQjCNHqsSMi4lUfksV9FuAaQRNHyYpkeQ . Accessed 3/6/2017.

Grengs, J. (2004): “The Abandoned Social Goals of Public Transit in the Neoliberal City of the USA”. *City*, Vol. 9, No. 1, Routledge, pp.51-66. [online] Available at http://www-personal.umich.edu/~grengs/files/Grengs2005_AbandonedSocialGoalsPublicTransitNeoliberalCity_City.pdf. Accessed 6/7/2017.

Haboucha, C. J., Ishaq, R., Shiftan, Y. (2017): “User preferences regarding autonomous vehicles”, *Transportation Research Part C* ,_vol. 78, Elsevier, pp. 37-49. [online] Available at: http://dx.doi.org/10.1016/j.trc.2017.01.010. Accessed 19/4/2017.

Harper, C. D., Hendrickson, C. T., Mangones, S., Samaras, C. (2016): “Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions”, *Transportation Research Part C* vol. 72, pp. 1-9. [online] Available at: http://dx.doi.org/10.1016/j.trc.2016.09.003. Accessed 2/5/2017.

Hohenberger, C., Spörrle, M., Welpe, I. M. (2016): “How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups”, *Transportation Research Part A* vol. 94, Elsevier, pp. 374-385. [online] Available at: https://doi.org/10.1016/j.tra.2016.09.022 . Accessed 19/3/2017.

Holm, M.S. (2017b): “Selvkorende Busser i Aalborg (Self-driving Buses in Aalborg)” [In Danish]. [presentation] Autodrive conference, 23 March

Hoy, D.C. (1993): “Heidegger and the Hermeneutics Turn”, in *The Cambridge Companion to Heidegger*. Cambridge University Press: Cambridge

Institute of Communication and Computer Systems (ICSS) (2015): “Technical Specifications of CityMobil2 Vehicles (Τεχνική Έκθεση Οχήματος Citymobil2)” [In Greek]. School of Electrical and Computer Engineering, National Technical University of Athens, Athens.

Jensen, O. B., Lassen, C. (2011): “Mobility Challenges”, *Danish Journal of Geoinformatics and Land Management*. Vol. 46, No. 1, pp. 9-21. [online] Available at http://vbn.aau.dk/files/60853948/mobility_challenges.pdf . Accessed 8/6/2017.

Jensen, O.B. and Lassen, C. (2011): “Mobility Challenges”, *Danish Journal of Geoinformatics and Land Management*, Vol. 46, No. 1 pp. 9-12. Available online at http://vbn.aau.dk/files/60853948/mobility_challenges.pdf. Accessed 29/3/2017.

Kamp, A.H., Kalogerakos, G., Mogensen, J.K., Beqiri, V. (2016): “Influential Aspects of A Light Rail”. Semester Project, Master’s programme in Mobilities and Urban Studies, Aalborg University, Aalborg.

Karaberi, C. (2016): “CityMobil2 in Trikala”. Presentation to other Partners of CityMobil2 Project, 3/11/2016. *E-Trikala – Department of Research and Communication*.

Kickstart Forstaden (2014): “Aalborg East – Strengthening the local Centre and Upgrading the Tunnel Connection (Fortætning af Bydelscenter og Opgradering af Tunnelforbindelse)” [In Danish]. [online] Available at http://www.aalborg.dk/media/6268313/forundersoegelsesrapport_med-commitmentproces.pdf . Accessed 16/6/2017.

Koffman, D. (Consultant), Benn, H., Billings, S.A., Fu, L., Hemingson, T., Hull, G., Lupro, B., Menzies, B., Shaw, P.L., Swope, M., Wiggins, W. (2004): "Operational Experiences with Flexible Transit Services". Transit Cooperative Research Program Synthesis 53, *Transportation Research Board.* [online] Available at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_syn_53.pdf . Accessed 6/7/2017.

König, M., Neumayr, L. (2017): "User's Resistance Towards Radical Innovations: the Case of the Self-driving Car". *Transportation Research Part F: Traffic Psychology and Behaviour*, vol.44, pp.42-52, Elsevier, January. [online] Available at http://dx.doi.org/10.1016/j.trf.2016.10.013 . Accessed 4/4/2017.

König, M., Neumayr, L. (2017): "Users' resistance towards radical innovations: The case of the self-driving car", *Transportation Research Part F* vol. 44, Elsevier, pp. 42-52. [online] Available online at http://dx.doi.org/10.1016/j.trf.2016.10.013. Accessed 28/4/2017.

Krueger, R., Rashidi, T. H., Rose, J. M. (2016): "Preferences for shared autonomous vehicles", *Transportation Research Part C* vol. 69, Elsevier, pp. 343-355. [online] Available from: http://dx.doi.org/10.1016/j.trc.2016.06.015. Accessed 3/4/2017.

Kvale, S. (2007): *Doing Interviews*. London: SAGE Publications.

Kyed, M. (2017b): "Samfundsøkonomiske gevinster ved Førerløse biler (Socioeconomic Gains with Driverless Cars)" [In Danish]. [presentation] *IDA (Danish Society of Engineers).*

Kyriakidis, M., Happee, R., de Winter, J. C. F. (2015): "Public opinion on automated driving: Results of an international questionnaire among 5000 respondents", *Transportation Research Part F* vol. 32, Elsevier, pp. 127-140. [online] Available at: http://dx.doi.org/10.1016/j.trf.2015.04.014. Accessed 4/4/2017.

Lanng, D. B., Harder, H., Jensen, O. B. (2012): "Towards urban mobility designs: *en route* in the functional city", *Artikler fra Trafikdage på Aalborg Universitet (Proceedings from the Annual Transport Conference at Aalborg University).* [online] Available at: http://www.trafikdage.dk/papers_2012/56_DitteBendixLanng.pdf . Accessed 4/6/2017.

Lassen, C. (2016): "A Global (and Mobile) Sense of Place". Lecture 2 presentation, *Mobilities: Policy, Branding and Place Management, School of Architecture, Design and Planning, Aalborg University*, Aalborg.

Lee, J.-G., Kim K. J., Lee S. & Shin D.-H. (2015): "Can Autonomous Vehicles Be Safe and Trustworthy? Effects of Appearance and Autonomy of Unmanned Driving Systems", *International Journal of Human–Computer Interaction*, vol. 31, issue 10, Taylor and Francis, pp. 682-691. [online] Available at: http://dx.doi.org/10.1080/10447318.2015.1070547. Accessed 4/4/2017.

Lioris, J., Pedarsani, R., Tascikaraoglu, F.Y., Varaiya, P. (2017): "Platoons of Connected Vehicles Can Double Throughput in Urban Roads". *Transportation Research Part C*, Vol. 77, Elsevier, pp. 292-305. [online] Available online at http://dx.doi.org/10.1016/j.trc.2017.01.023. Accessed 2/4/2017.

Lioris, J., Pedarsani, R., Yildiz Tascikaraoglu, F., Varaiya, P. (2017): "Platoons of connected vehicles can double throughput in urban roads", *Transportation Research Part C* vol. 77, Elsevier, pp. 292-305. [online] Available at: http://dx.doi.org/10.1016/j.trc.2017.01.023. Accessed 7/6/2017.

Loon, R. J., Martens, M. H. (2015): "Automated driving and its effect on the safety ecosystem: How do compatibility issues affect the transition period?", *Procedia Manufacturing* vol. 3, University of Twente, pp. 3280-3285. [online] Available at http://doc.utwente.nl/100371/1/1-s2.0-S2351978915004023-main.pdf . Accessed 6/9/2017.

Lu, Z., Du, R., Dunham-Jones, E., Park, H., Crittenden, J. (2017): "Data-enabled public preferences inform integration of autonomous vehicles with transit-oriented development in Atlanta", *Cities*, vol.63, Elsevier, pp. 118-127. [online] Available at: http://dx.doi.org/10.1016/j.cities.2017.01.004. Accessed 2/7/2017.

Lutz, L.S. (2016): "Automated Vehicles in the EU: Proposals to Amend the Type Approval Framework and Regulation of Driver Conduct". *Causalty Matters*, Gen.Re, [online] Available at http://www.genre.com/knowledge/publications/cmint16-1-en.html . Accessed 18/6/2017.

Madigan, R., Louw, T., Dziennus, M., Graindorge, T., Ortega, E., Graindorge, M., Merat, N. (2016): "Acceptance of Automated Road Transport Systems (ARTS): an adaptation of the UTAUT model", Transportation Research Procedia, vol. 14, Elsevier, pp. 2217-2226. [online] Available at http://eprints.whiterose.ac.uk/100607/8/1-s2.0-S2352146516302435-main.pdf . Accessed 26/3/2017.

Manning, J. (2013): "A Look into Autonomous Vehicles". Student presentation, COSC 380 Seminar on the Computer Profession and Ethics, Indiana University of Pennsylvania. [online] Available at www.iup.edu/WorkArea/DownloadAsset.aspx?id=170629 . Accessed 23/7/2017.

Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P. and Marrs, A. (2013): "Disruptive Technologies: Advances that Will Transform Life, Business and The Global Economy", *McKinsey Global Institute*. [online] Available at http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/disruptive-technologies. Accessed 17/3/2017.

Molonis, Z., Bletsas, K. (2016): "Web Application for Municipality Self-Evaluation in the context of Smart Cities (Διαδικτυακή Εφαρμογή Αυτοαξιολόγησης Δήμων στα Πλαίσια Δράσεων Έξυπνης Πόλης)" [In Greek]. Postgraduate thesis, University of the Aegean. [online] Available at http://hellanicus.lib.aegean.gr/bitstream/handle/11610/16999/Smart%20Cities.pdf?sequence=1 . Accessed 7/6/2017.

Municipality of Trikala (2015): "Municipality of Trikala Strategic Planning 2014-2019 (Δήμος Τρικκαίων: Στρατηγικός Σχεδιασμός Επιχειρησιακού Προγράμματος 2014-2019)" [In Greek]. [online] Available at http://trikalacity.gr/wp-content/uploads/2016/03/stratigikos-sxediasmos.pdf. Accessed 5/6/2017.

Navya website (2015): "Arma:Press Kit". [online] Available at https://navya.tech/wp-content/uploads/2015/09/NavyaPressRelease.pdf . Accessed 26/7/2017.

Payre, W., Cestac, J., Delhomme, P. (2014): "Intention to use a fully automated car: Attitudes and a priori acceptability", *Transportation Research Part F* vol. 27, Elsevier, pp. 252-263. [online] Available at: http://dx.doi.org/10.1016/j.trf.2014.04.009. Accessed 5/4/2017.

Piao, J., McDonald, M., Hounsell, N., Graindorge, M., Graindorge, T., Malhene, N. (2016): "Public views towards implementation of automated vehicles in urban areas", *Transportation Research Procedia* vol. 14, Elsevier, pp. 2168-2177. [online] Available at https://doi.org/10.1016/j.trpro.2016.05.232 . Accessed 4/4/2017.

Pillath, S. (2016): "Automated Vehicles in the EU", *European Parliament Research Service (EPRS).* [online] Available at http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573902/EPRS_BRI(2016)573902_EN.pdf. Accessed 3/4/2017

Raney, S., Young, S. (2004): “Morgantown People Mover – Updated Description” [presentation] *Transportation Research Board Annual Meeting in 2005at Washington, D.C.*. [online] Available at: http://www.cities21.org/morgantown_TRB_111504.pdf. Accessed 5/3/2017.

Rigole, P.-J. (2014): “Study of a Shared Autonomous Vehicles Based Mobility Solution in Stockholm”. *Master’s Thesis at KTH, Stockholm*. [online] Available at http://kth.diva-portal.org/smash/get/diva2:746893/FULLTEXT01.pdf . Accessed 3/4/2017.

Rudin-Brown, C. and Noy, Y.I. (2002): “Investigation of Behavioural Adaptation to Lane Departure Warnings”. *Transportation Research Record* Journal 1803 (1), Transportation Research Board pp. 30-37. Available at https://www.researchgate.net/publication/245560355_Investigation_of_Behavioral_Adaptation_to_Lane_Departure_Warnings. Accessed 26/6/2017.

Ryley, T. J., Stanley, P. A., Enoch, M. P., Zanni, A. M., Quddus, M. A. (2014): “Investigating the contribution of Demand Responsive Transport to a sustainable local public transport system”, *Research in Transportation Economics*, vol. 48, Elsevier, pp. 364-372. [online] Available at: http://dx.doi.org/10.1016/j.retrec.2014.09.064. Accessed 24/5/2017.

Sandel, M. J. (2009): *Justice: What's the Right Thing to Do?*, New York: Farrar, Strauss and Giroux. [Cited in the Greek Translation of A. Kioupkiolis (2013), Athens: Polis].

Solis, B. (2017): “The Race to 2021: The State of Autonomous Vehicles and a “Who’s Who” of Industry Drivers”. *Altimeter*. [online] Available at https://www.slideshare.net/Altimeter/the-race-to-2021-the-state-of-autonomous-vehicles-and-a-whos-who-of-industry-drivers . Accessed 5/7/2017.

Suloppuisto, O. (2016): “Why Helsinki’s Innovative On-demand Bus Service Failed?”, *Cityscope.* [online] Available at http://citiscope.org/story/2016/why-helsinkis-innovative-demand-bus-service-failed. Accessed 21/5/2017.

United Nations Economic Commission for Europe (UNECE) (1968): "Convention on Road Traffic Done at Vienna on 8 November 1968". [online] Available at https://www.unece.org/fileadmin/DAM/trans/conventn/crt1968e.pdf . Accessed 2/7/2017.

United Nations Treaty Collection (1949): "1. Convention on Road Traffic, Geneva, 19 September 1949". [online] Available at https://treaties.un.org/doc/Publication/MTDSG/Volume%20I/Chapter%20XI/XI-B-1.en.pdf . Accessed 2/7/2017.

United Nations Treaty Collection (1968): "19. Convention on Road Traffic, Vienna, 8 November 1968". [online] Available at https://treaties.un.org/doc/Publication/MTDSG/Volume%20I/Chapter%20XI/XI-B-19.en.pdf . Accessed 5/7/2017.

Urban and Regional Innovation Research (2008): "Digital and Smart Cities: Notions, Examples and core Technologies (Ψηφιακές και Έξυπνες Πόλεις: Έννοιες, Παραδείγματα, Βασικές Τεχνολογίες)" [In Greek]. [online] Available at http://www.urenio.org/el/wp-content/uploads/2008/10/Digital__Intelligent_Cities_Concepts_Examples_and_Core_Technologies.pdf . Accessed 5/6/2017.

Urry, J. (2007): *Mobilities*. Cambridge: Polity

Vasilogiannis, P.H. (2014): lecture notes, "Introduction to Jurisprudence". *Law school, National and Kapodistrian University of Athens*

Wietholt, T., Harding, J. (2016): "Influence of Dynamic Traffic Control Systems and Autonomous Driving on Motorway Traffic Flow". *Transport Research Procedia*, vol. 15, Elsevier, pp. 176-186, June. [online] Available at https://doi.org/10.1016/j.trpro.2016.06.015. Accessed 28/5/2017.

Wietholt, T., Harding, J. (2016): "Influence of dynamic traffic control systems and autonomous driving on motorway traffic flow". *Transportation Research Procedia* vol. 15, Elsevier, pp. 176-186. [online] Available at http://dx.doi.org/10.1016/j.trpro.2016.06.015. Accessed 25/5/2017.

Yap, M. D., Correia, G., van Arem, B. (2016): "Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips". *Transportation Research Part*

A vol. 94, Elsevier, pp. 1-16. [online] Available at: http://dx.doi.org/10.1016/j.tra.2016.09.003 . Accessed 22/4/2017.

Zhang, W., Guhathakurta, S., Fang, J., Zhang, G. (2015): "Exploring the impact of shared autonomous vehicles on urban parking demand: An agent-based simulation approach". *Sustainable Cities and Society*, vol. 19, Elsevier, pp. 34-45. [online] Available at: http://dx.doi.org/10.1016/j.scs.2015.07.006 . Accessed 7/7/2017.

Zhang, W., Guhathakurta, S., Fang, J., Zhang, G. (2015): "Exploring the Impact of Shared Autonomous Vehicles on Urban Parking Demand: An Agent-Based Simulation Approach", *Sustainable Cities and Society*, Vol. 19, Elsevier, pp. 34-45, December. Available at https://doi.org/10.1016/j.scs.2015.07.006. Accessed at 2/4/2017

Interviews

Egense, A. (2017): Personal interview in Danish Road Directorate on 16 March

Karaberi, C. (2017): Personal interview at the establishments of E-Trikala SA on 22 March

Kyed, M. (2017a): Personal interview at the Headquarters of Danish Society of Engineers (IDA) on 16 March

Lange, D. (2017): Personal interview at the Headquarters of Danish Federation of Motorists (FDM) on 31 March

Raptis, O. (2017): Personal interview at the establishments of E-Trikala SA on 22 March

Holm, M. (2017a): Personal interview at her office at the Department of Spatial and Environmental Management of Aalborg Municipality on 7 April

Sørensen, N. (2017): Personal interview at his office in Northern Jutland Transport Agency (NT) on 7 April

Vavitsas, L. (2017): Personal interview at the establishments of E-Trikala SA on 22 March

Websites

2getthere website (2017): "Masdar PRT". [online] Available at https://www.2getthere.eu/projects/masdar-prt/ . Accessed 5/3/2017.

Aalborg Municipality (2017a): "Aalborg East (Det østlige Aalborg)" [In Danish]. [online] Available at http://www.aalborg.dk/om-kommunen/byplanlaegning/byudvikling/det-oestlige-aalborg. Accessed 7/6/2017.

Aalborg Municipality (2017b): "Main Structure 2013 – A Spatial Vision 2025 for Aalborg (Hovedstruktur 2013 - en Fysisk Vision 2025 for Aalborg Kommune)" [In Danish]. [online] Available at http://www.aalborg.dk/om-kommunen/byplanlaegning/bystrategi/fysisk-vision-2025 . Accessed 7/6/2017.

Aalborg University (2017): "Aalborg's History". [online] Available at http://www.sasp2017.aau.dk/About+Aalborg/ . Accessed 25/5/2017.

Anderson, J.E. (1996): "Some Lessons from the History of Personal Rapid Transit (PRT)". [online] Available at http://faculty.washington.edu/jbs/itrans/history.htm . Accessed 31/7/2017.

Autocar UK (2016): "Google Waymo Self-driving Car Company Announced". [online] Available at https://www.autocar.co.uk/car-news/new-cars/google-waymo-self-driving-car-company-announced . Accessed 4/3/2017.

Automotive News (2015): "Tesla Beams down "Autopilot" Mode to Model S". [online] Available at http://www.autonews.com/article/20151014/OEM06/151019938/tesla-beams-down-autopilot-mode-to-model-s . Accessed 4/3/2017.

Car and Driver (2016): "Semi-Autonomous Cars Compared! Tesla Model S vs. BMW 750i, Infiniti Q50S and Mercedes S65 AMG". [online] Available at http://www.caranddriver.com/features/semi-autonomous-cars-compared-tesla-vs-bmw-mercedes-and-infiniti-feature . Accessed 3/3/2017.

Carnegie Mellon University (CMU) (2017): "No Hands Across America". School of Computer Science. [online] Available at http://www.cs.cmu.edu/~tjochem/nhaa/nhaa_home_page.html . Accessed 3/3/2017.

Carscoops.com (2016): "Vauxhall Corsa Shows Off Advanced Park Assist Tech with Dog in Driver's Seat [w/Video]". [online] Available at http://www.carscoops.com/2016/03/vauxhall-corsa-shows-off-advanced-park.html . Accessed 3/6/2017.

CityMobil2 (2016c): "CityMobil2: Trikala" [video]. [online] Available at https://www.youtube.com/watch?v=pLsmsTj393o . Accessed 9/7/2017.

CityLab (2014): "Personal Rapid Transit Is probably never Going to Happen". [online] Available at https://www.citylab.com/life/2014/09/personal-rapid-transit-is-probably-never-going-to-happen/380467/ . Accessed 5/3/2017.

Computer History Museum (2014): "Where to? A History of Autonomous Vehicles". [online] Available at http://www.computerhistory.org/atchm/where-to-a-history-of-autonomous-vehicles/. Accessed 4/3/2017.

Crash Online (2015a): " The "Headless monster", which terrorizes citizens! "Kick out Satanic Robot"(pictures)"! [Το «Ακέφαλο Τέρας» , που Τρομοκρατεί τους Πολίτες! «Διώξτε το Σατανικό Ρομπότ»! (Φωτό)]" [In Greek]. [online] Available at http://www.crashonline.gr/%CF%84%CE%BF-%CE%B1%CE%BA%CE%B5%CF%86%CE%B1%CE%BB%CE%BF-%CF%84%CE%B5%CF%81%CE%B1%CF%83-%CF%80%CE%BF%CF%85-%CF%84%CF%81%CE%BF%CE%BC%CE%BF%CE%BA%CF%81%CE%B1%CF%84%CE%B5%CE%B9-%CF%84%CE%BF%CF%85/ . Accessed 20/6/2017.

Crash Online (2015b): "Trikala driverless bus crashed! Autopilot… lost control (Τράκαρε το Λεωφορείο χωρίς Οδηγό στα Τρίκαλα! Ο… Αυτόματος Έχασε τον Έλεγχο!) [In Greek]. [online] Available at http://www.crashonline.gr/%CF%84%CF%81%CE%B1%CE%BA%CE%B1%CF%81%CE%B5-%CF%84%CE%BF-%CE%BB%CE%B5%CF%89%CF%86%CE%BF%CF%81%CE%B5%CE%B9%CE%BF-%CF%87%CF%89%CF%81%CE%B9%CF%83-%CE%BF%CE%B4%CE%B7%CE%B3%CE%BF-%CF%83%CF%84%CE%B1-%CF%84/ . Accessed 21/6/2017.

Copenhagen Metro Company website (København Metroselskabet) (2017): "Safety and Service". [online] Available at http://intl.m.dk/#!/about+the+metro/travel+information/safety . Accessed 18/7/2017.

Danish Road Directorate (Vejdirektoratet) (2017a): "Lang Vej til den Selvkørende Bilpark (Long way until the Self-driving Car Parking)". [online] Available at https://pbs.twimg.com/media/C3vnJGxWIAAPSH9.png . Accessed 3/7/2017.

Danish Road Directorate (Vejdirektoratet) (2017b): "Selvkørende Biler (Self-driving Cars)". [online] Available at http://vejdirektoratet.dk/DA/viden_og_data/temaer/Selvkoerendebiler/Sider/Default.aspx . Accessed 3/7/2017.

Deutsche Bahn (2017): "Autonomous Driving – Mobility in Transition". [online] Available at http://www.deutschebahn.com/en/Digitalization/Autonomous_driving.html . Accessed 6/3/2017.

Die Welt (2016): "Die Bahn will Busse ohne Fahrer Einführen (German Railways Want to Introduce Buses without Drivers)" [In German]. [online] Available at https://www.welt.de/wirtschaft/article160381286/Die-Bahn-will-Busse-ohne-Fahrer-einfuehren.html . Accessed 4/3/2017.

Digital Trends (2017): "Driverless Buses Arrive in Paris". [online] Available at http://www.digitaltrends.com/cars/paris-driverless-buses/ . Accessed 10/3/2017.

Engineering.com (2016): "The Road to Driverless Cars 1925-2025". [online] Available at http://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/12665/The-Road-to-Driverless-Cars-1925--2025.aspx . Accessed 4/3/2017.

European Commission (2016): "Commission Announces the Finalists of the European Sustainable Urban Mobility Awards". [online] Available at https://ec.europa.eu/transport/themes/urban/news/2016-03-15-sump-award-finalists_en . Accessed 17/6/2017.

Forbes (2016): "Should Carmakers Be Liable when a Self-driving Car Crashes?". [online] Avalable at https://www.forbes.com/sites/omribenshahar/2016/09/22/should-carmakers-be-liable-when-a-self-driving-car-crashes/#56ad074a48fb . Accessed 18/6/2017.

Ford (2017a): "2017 Transit XL Passenger Wagon". [online] Available at http://www.ford.com/commercial-trucks/transit-cargo-van/2017/models/transit-xl-passenger-van/ . Accessed 26/7/2017.

Ford (2017b): "Active Park Assist". [online] Available at https://owner.ford.com/how-tos/vehicle-features/convenience-and-comfort/active-park-assist.html . Accessed 12/6/2017.

Fortune Greece (2017): "Trikala: A Greek "Good Example" of Smart City (Τρίκαλα: Ένα Ελληνικό «Καλό Παράδειγμα» Έξυπνης Πόλης)" [In Greek]. [online] Available at http://www.fortunegreece.com/article/trikala-ena-elliniko-kalo-paradigma-exipnis-polis/ . Accessed 5/6/2017.

Google Maps (2017): Maps.google.com

Hellenic Broadcasting Corporation (2016): "Trikala: last-year's record of 950.000 visitors of the "Mill of the Elves" is about to be broken (Τρίκαλα: Αγγίζει το Περσινό Ρεκόρ των 950.000 Επισκεπτών ο «Μύλος των Ξωτικών»)" [In Greek]. [online] Available at http://www.ert.gr/perifereiakoi-stathmoi/trikala-angizi-to-persino-rekor-me-950-000-episkeptes-o-milos-ton-xotikon/ . Accessed 21/7/2017.

Iefimerida.gr (2015): "Trikala driverless bus crashed! (Τράκαρε το Λεωφορείο χωρίς Οδηγό στα Τρίκαλα)" [In Greek]. [online] Available at http://www.iefimerida.gr/news/237837/trakare-leoforeio-horis-odigo-sta-trikala#axzz4h3nzJKHI . Accessed 21/6/2017.

Image.superstreetonline.com (2017): "Visionary Normal Bel Geddes Highway". [online] Available at http://image.superstreetonline.com/f/27065978%20w%20h%20q80%20re0%20cr1/epcp-1004-02-hp+visionary-norman-bel-geddes+superhighway.jpg . Accessed 27/7/2017.

Inside-handy.de (2016): "Deutsche Bahn Startet Autonom Fahrende Buslinien (Deutsche Bahn starts driverless Bus Lines)" [In German]. [online] Available at https://www.inside-handy.de/news/43198-db-bus-olli-autonom . Accessed 3/3/2017.

Intelligent Community Forum (ICF) (2017): "The Smart 21 Communities of the Year". [online] Available at http://www.intelligentcommunity.org/smart21 . Accessed 9/6/2017.

Just Auto (2016): "Ford Ramps up ADAS on New Fiesta". [online] Available at http://www.just-auto.com/news/ford-ramps-up-adas-on-new-fiesta_id173685.aspx . Accessed 12/6/2017.

Keyword Suggest Encyclopedia (2016): "Image Gallery: PRT". [online] Available at http://keywordsuggest.org/gallery/610328.html . Accessed 5/3/2017.

Localit.gr (2015): "The Role of Municipalities in Creating Smart Cities – Examples of Greek Smart Cities (Η Στρατηγική των Έξυπνων Πόλεων και οι Δήμοι – Παραδείγματα Ελληνικών Smart Cities)" [In Greek]. [online] Available at http://www.localit.gr/archives/86945 . Accessed 7/6/2017.

Mercedes-Benz Vans (2017): "Sprinter Passenger Van". [online] available at https://www.mbvans.com/sprinter/commercial-vans/passenger-van . Accessed 26/7/2017.

Ministry of Transport, Building and Housing (Transport-, Bygnings- og Boligministeriet) (2017): "Minister Prepares Legislation for self-driving Cars (Minister forbereder lovgivning til selvkørende biler)" [In Danish]. [online] Available at https://www.trm.dk/da/nyheder/2017/minister-forbereder-lovgivning-til-selvkoerende-biler . Accessed 5/5/2017.

Municipality of Trikala old website (2017): "E-Trikala S.A. Fields of Specialization (E-Trikala A.E. Τομείς Εξειδίκευσης)" [In Greek]. [online] Available at http://old.trikalacity.gr/node/85824 . Accessed 5/6/2017.

Myota.gr (2016): "Driverless bus project was successful (Επιτυχημένο το Λεωφορείο χωρίς Οδηγό)" [In Greek]. [online] Available at http://www.myota.gr/index.php/dimotikes-draseis/8283-2016-03-17-09-49-51. Accessed 5/7/2017.

National Geographic News (2016): "Watch a Driverless Bus Putter Through the Streets". [online] Available at http://news.nationalgeographic.com/2016/03/160325-self-driving-bus-automation-video/ . Accessed 7/6/2017.

Patras Events website (2014): "Trikala: The Wooden Bicycle that Became Viral in Social Media (Τρίκαλα: Το Ξύλινο Ποδήλατο που «Σαρώνει» στα Social Media)" [In Greek]. [online] Available at https://www.patrasevents.gr/article/129494-trikala-to-ksilino-podilato-pou-saronei-sta-social-media-pics . Accessed 17/6/2017.

Podilates Trikalon website (2017): "Who Are We? (Ποιοι Είμαστε;)" [In Greek]. [online] Available at https://podilatestrikalon.wordpress.com/%CF%80%CE%BF%CE%B9%CE%BF%CE%B9-%CE%B5%CE%AF%CE%BC%CE%B1%CF%83%CF%84%CE%B5/ . Accessed 17/6/2017.

Proto Thema website (2015): " "Kick out satanic robot": "War" in Trikala Regarding Headless Bus! («Διώξτε το Σατανικό Ρομπότ»: «Πόλεμος» στα Τρίκαλα για το Ακέφαλο Λεωφορείο!)" [In Greek]. [online] Available at http://www.protothema.gr/greece/article/519058/polemos-sta-trikala-gia-to-akefalo-leoforeio-/ . Accessed 20/6/2017.

PRT Consulting (2015): "Masdar City Personal Rapid Transit". [online] Available at http://www.prtconsulting.com/gallery11.html . Accessed 6/3/2017.

Reuters (2016): "Tesla Crash Raises Concerns about Autonomous Vehicle Regulation". [online] Available at http://www.reuters.com/article/us-tesla-autopilot-idUSKCN0ZH4VO . Accessed 14/6/2017.

Snoopit.com (2015): "Trikala Innovate with a Robot-bus (Τα Τρίκαλα Πρωτοπορούν με Λεωφορείο-ρομπότ)" [In Greek]. [online] Available at https://snoopit24.com/2015/10/13/%CF%84%CE%B1-%CF%84%CF%81%CE%B9%CE%BA%CE%B1%CE%BB%CE%B1-%CF%80%CF%81%CF%89%CF%84%CE%BF%CF%80%CE%BF%CF%81%CE%BF%CF%85%CE%BD-%CE%BC%CE%B5-%CE%BB%CE%B5%CF%89%CF%86%CE%BF%CF%81%CE%B5%CE%B9%CE%BF-%CF%81/ . Accessed 18/6/2017.

Society of Automotive Engineers (SAE) (2014): "Automated Driving: Levels of Driving Automation Are Defined in New SAE International Standard J3016". [online] Available at http://www.sae.org/misc/pdfs/automated_driving.pdf . Accessed 26/2/2017.

Team Vandkunsten (2017): "Start of Works Ceremony in Tornhøj (Første spadestik i Tornhøj)" [In Danish]. [online] Available at http://vandkunsten.com/da/aktuelt/forste-spadestik-tornhoj. Accessed 17/6/2017.

Teknik Nyt (2017): “Selvkørende Biler Bliver en Realitet i København (Self-driving Vehicles Become a Reality in Copenhagen)”. [online] Available at http://tekniknyt.dk/selvkoerende-biler-realitet-koebenhavn/ . Accessed 7/3/2017.

The Local (Germany) (2016): “Driverless Bus “Olli” Undergoes Testing in Berlin”. [online] Available at https://www.thelocal.de/20161215/driverless-bus-olli-undergoes-testing-in-berlin . Accessed 4/3/2017.

The Telegraph (2016): “World's first Driverless Bus Service Begins Carrying Passengers in French City of Lyon”. [online] Available at http://www.telegraph.co.uk/news/2016/09/03/worlds-first-driverless-bus-service-begins-carrying-passengers-i/ . Accessed 2/4/2017.

Theatlantic.com (2016): “Your Grandmother’s Driverless Car”. [online] Available at https://www.theatlantic.com/technology/archive/2016/06/beep-beep/489029/ . Accessed 4/3/2017.

Toyota Global (2012): “75 Years of Toyota - Technical Development – Electronic Parts”. [online] Available at http://www.toyota-global.com/company/history_of_toyota/75years/data/automotive_business/products_technology/technology_development/electronics_parts/index.html . Accessed 20/702017.

Trikala Day website (2015a): “Trikala driverless bus got crazy: It mounted the pavement and ran over a kiosk (Τρελάθηκε το Λεωφορείο χωρίς Οδηγό στα Τρίκαλα: Καβάλησε το Πεζοδρόμιο και Κατέληξε σε Περίπτερο!)” [In Greek]. [online] Available at http://www.trikaladay.gr/trelathike-to-leoforio-choris-odigo-sta-trikala-kavalise-to-pezodromio-ke-katelixe-se-periptero-foto . Accessed 21/6/2017.

Trikala Day website (2015b): “See what will be included this year in the “Mill of the Elves” in Trikala (Δείτε τι θα περιλαμβάνει φέτος ο Μύλος των Ξωτικών στα Τρίκαλα)” [In Greek]. [online] Available at http://www.trikaladay.gr/dite-ti-tha-perilamvani-fetos-o-milos-ton-xotikon-sta-trikala . Accessed 21/7/2017.

Trikalain.gr (2017): “ “Green Fund” will Provide the Grant for the Execution of the Sustainable Urban Mobility Plan of Trikala (Χρήματα από το «Πράσινο Ταμείο» για την Υλοποίηση του ΣΒΑΚ Τρικάλων)” [In Greek]. [online] Available at http://trikalain.gr/xrimata-apo-prasino-tamio-gia-tin-ylopiisi-tou-svak-trikalon/ . Accessed 17/6/2017.

Trikalaola.gr (2015): "Why Driverless Bus Deviated from its Course? Safety Demonstration in front of the Camera, 27/11/2015 (Γιατί το Λεωφορείο χωρίς Οδηγό Παρέκκλινε της Πορείας του; Πείραμα Ασφαλείας μπροστά στην Κάμερα, 27/11/2015)" [video] [In Greek]. [online] Available at https://www.youtube.com/watch?v=ZyjFbS6pxdY . Accessed 21/6/2017.

Trikalaview.gr (2015): "Indictment Regarding Driverless Bus in Trikala will be Unsealed on Friday (Την Παρασκευή η Μήνυση για το Λεωφορείο χωρίς Οδηγό) [In Greek]. [online] Available at https://trikalaview.gr/%CF%84%CE%B7%CE%BD-%CF%80%CE%B1%CF%81%CE%B1%CF%83%CE%BA%CE%B5%CF%85%CE%AE-%CE%B7-%CE%BC%CE%AE%CE%BD%CF%85%CF%83%CE%B7-%CE%B3%CE%B9%CE%B1-%CF%84%CE%BF-%CE%BB%CE%B5%CF%89%CF%86%CE%BF%CF%81%CE%B5%CE%AF/ . Accessed 21/6/2017.

TV2 News (2017): "Driverless Bus comes to Denmark (Forerlose Busser kommer til Danmark)" [video]. [online] Available at http://nyheder.tv2.dk/samfund/2017-06-30-busser-uden-chauffoer-testet-i-aalborg-naeste-aar-bliver-det-hverdag . Accessed 22/7/2017.

Ultra Global PRT (2017): "Heathrow T5". [online] Available at http://www.ultraglobalprt.com/wheres-it-used/heathrow-t5/ . Accessed 5/3/2017.

United Nations Economic Commission for Europe (UNECE) (2016): "UNECE Paves the Way for Automated Driving by Updating UN International Convention". [online] Available at http://www.unece.org/info/media/presscurrent-press-h/transport/2016/unece-paves-the-way-for-automated-driving-by-updating-un-international-convention/doc.html . Accessed 3/7/2017.

Vesthimmerland Municipality (2017): "Vesthimmerlands Kommune Vil Have Selvkørende Biler på Vejene (Vesthimmerland Municipality will Have Self-driving Cars on Streets)" [In Danish]. [online] Available at http://vesthimmerland.dk/kommunen/nyheder/seneste-nyt/nyheder/vesthimmerlands-kommune-vil-have-selvkoerende-biler-paa-vejene/ . Accessed 4/3/2017.

Waymo homepage (2017). [online] Available at https://waymo.com/ . Accessed 3/3/2017.

Web Urbanist (2015): "Driverless Living Space: Future Car Envisioned as Mobile Room". [online] Available at http://weburbanist.com/2015/01/13/driverless-living-space-future-car-envisioned-as-mobile-room/ . Accessed 2/4/2017.

West Virginia University (2017): "Transportation and Parking". [online] Available at http://transportation.wvu.edu/prt . Accessed 5/3/2017.

Zougla.gr (2015): "Trikala Driverless Bus Crashed (Τράκαρε το Λεωφορείο χωρίς Οδηγό που Κυκλοφορεί στα Τρίκαλα)" [In Greek]. [online] Available at http://www.zougla.gr/automoto/paraxena/diafora/article/trakare-to-leoforio-xoris-odigo-pou-kiklofori-sta-trikala . Accessed 21/6/2017.

9. APPENDIX

A. Interview transcripts

Andreas Egense, Head of the Sector Analysis Department, Danish Road Directorate (Vejdirektoratet). Interview at Vejdirektoratet headquarters in Copenhagen, Denmark on 16/3/2017.

G.K.: Why should we implement driverless mobilities?

A.E.: There are several reasons why we should do that. First of all because they're going to increase mobility in our society; we will have the possibility for better use of travel time, to have more traffic in a sense we will have more cars at a time on a strip, on a road. And then we will have an impact on safety because for many reasons they will reduce traffic accidents. They will also make goods, labour, services and so on to become mobile more easily than today. Therefore it will be a good thing for society to get AV. However they are not necessarily going to solve the problem of congestion, as AV are going to attract those who are now not able to drive.

G.K.: You also have a study about that; how do you thing this problem - increase in congestion by AV - can be alleviated?

A.E.: There could be a kind of equilibrium. It can be that at some point there will be so much traffic, that demand for taking the trips will fall, if it takes so much time to go from one point to another. Congestion reaches a level that there is no more traffic coming through. Of course that's not the solution because it will waste much of people's time in traffic. You can solve this problem in several different ways. Another way to solve congestion problem is to ban all traffic. If you ban all traffic, you close up the streets then by definition there will be no more congestion. But this will not be good for society because it will be very difficult for people, goods etc. to get around. Then of course you can work on the capacity of the streets, of the roads. The typical way to increase capacity is to build new roads, to build wider roads. Then we can see what we can do in order to increase capacity on the same space. There are different solutions for that, for example the possibility to drive closer, to decrease [vertical] distances between the cars, which will increase capacity on the road. You can also do that in a horizontal way, because maybe these vehicles will be able to keep the lane very very precisely. Today lanes are a bit wide because it is taken into account cars can move a bit around. But if you have vehicles that are able to keep the lane with high precision you can decrease the width of the road. You can also look at times when you have much traffic; peak hours, such as when you have high volumes of traffic coming into the city in the morning and in the evening it’s going the other way around, you have much traffic going out of the city. In this case you can have variable lanes that are either on the one or on the other direction. In this case it’s also an issue that there is hard separation material between two directions; we have to find a way to move this separation. There are ways to do that. Then we could of course take out the emergency lane of the motorway in peak hours, when there is a lot of traffic. There are also the so-called High Occupancy Vehicle (HOV) lanes, something that was done in the United States; you can use those lanes if there are more people in the same car. So one way to reduce congestion is to have more people on the same car. Today on average in Denmark there is 1,4 people in the car, which typically could be 4 people. So when you get more people into the car you’ll get a new way to reduce congestion. But if you look historically you’ll see fewer and fewer people are getting into the same car; are driving together. So it’s not given you can have more people in the same car. Therefore if you wanna have more people to do it you have to put incentives for that, and HOV lanes are such one. They will be an incentive for more people to drive together. The problem is that if you get them in one lane you’re actually taking up capacity on the road. So it’s only a solution that will actually decrease capacity if you don’t have people who choose to drive together. If you still have one person in the car it will not increase capacity to take out a lane that will be used by just one car. It might be that 80% of traffic is cars with one or two people, so you need some incentives for people to drive together. You can tax cars, tax fuel, you can have road pricing to split traffic so that people use the capacity outside peak hours. So the problem is peak hours, it’s not going out, it’s not in the middle of the day but it’s peak hours when capacity is a scarce resource.

G.K.: So if the emergency lane is removed, what will happen in case it is needed?

A.E.: They are working with using the emergency lane in countries like UK and what they do is they have a system that gives information to the traffic “now the lane is open you can use it” and if there is a need to use the lane they close it.

G.K.: Do you think shared cars can replace public buses?

A.E.: If we look into a scenario with AV, the distinction between a car where people are driving together and a public bus will not be that important. Basically the main cost in public transport is the labour cost, the wage you have to pay to the driver. Therefore buses are typically of high capacity to cover this cost. But if you don’t have this labour cost you can decrease the size of the bus and increase the frequency - how often the public transport will pass by the stop - and also expand the network. So it can be much closer to where you need to be and it can pick you up at much closer to where you are. In that regard, yes I think it can have some impact on public transport, on the network and the frequency.

G.K.: What about the legislative framework for AVs? Is it ready? Are there any preparations being made at the moment?

A.E.: Legislation is at different levels; there is international and domestic legislation. A lot of countries, including Denmark have signed Vienna Convention which has specific limits and what it does is it requires that all vehicles must have a driver who is able to control their vehicle or guide their animals. It’s from 1968, it’s quite old, that’s why it includes animals… You cannot have AV on a road before we change that convention, at least at a commercial level. However we can make tests with AV and as long as this legislation will be passed, anybody who is interested will be able to apply from July 1st for a test with AV. However now legislation does not require that you have your hands on the wheel and your feet on the pedals. It requires that you pay attention all the time, you understand traffic, the traffic surroundings and you’re ready to take over control of the vehicle.

G.K.: Could you state some of the important ethical and liability issues regarding AV?

A.E.: It is often put forward in discussion what should the vehicle do in a situation when an accident is inevitable and AV is gonna choose if it’s going up to an old woman or a mother with her child; and of course the situation there has to be taken into account. There is also a question on how you use capacity on a road. For example if you drive to Copenhagen in the morning and you leave in the afternoon you’ll pay a rather big amount of money for parking. There might be the possibility that the car moves around the city and comes after you finish your shopping and picks you up. Of course in that case we would have a ridiculous situation where empty cars would move around the city without reason. In another case the car could move out of the city centre and park by itself. And that’s a good idea, it will not take parking space in the city, it could drive empty to park and then drive empty to come back and pick you up. It sounds a good thing. There will also be a lot of dilemmas in the transition period when you have a mix of autonomous cars and conventional cars; and it might be difficult because there are things you can't do in mixed traffic. It will create situations where you have… For example we made a test with truck platooning in Denmark last May where the trucks that were connected could drive closer to each other, save energy and increase safety. Trucks were driving at 80 km/h (which was the speed limit) and another truck was overtaking them at 81 km/h. It was a situation where this truck did not have to overtake one truck but three, meaning all traffic was stuck behind the trucks in both lanes for let's say for a minute. This is not good utilization of capacity. That is an increase in congestion. So there will be a lot of situations you are about to face in the transition period and then you need to be able to optimize replacement along the way.

G.K.: What about the implementation of autonomous mobilities politically? Which powers in the society will support them and which will oppose them?

A.E.: Basically AV is a good thing, so I don't see many reasons why they should not be supported. Of course there is a question on how risk-willing the politicians are. Some might be more risk-willing than others. And of course there are politicians who are very much in favor of roads and there are politicians who are very much in favor of public transport. The politicians who are in favor of roads should give the opportunity because this thing is going to increase safety for society, while politicians who are in favor of public transport might prevent it. It's gonna be some time in the future when we will still have congestion problems and then we'll need public transport to relieve a part of congestion, like also walking and cycling.

Martin Kyed, Chief Economist, Head of the Department of Analysis, IDA [Danish Society of Engineers]. Interview at IDA headquarters in Copenhagen, Denmark on 16/3/2017.

G.K.: Why should we implement driverless mobilities?

M.K.: I think the most clear answer is a quite stupid one. It's due to their benefits. If you look at the enormous investments of car manufacturers and software companies, it seems that a lot of people out there can see substantial benefits for consumers; Otherwise they wouldn't invest so much in this technology. There might be something, as they think this is the key to win market shares in the future. So the reason they are spending that much – and employing a lot of engineers by the way – is that they may think this is the only way that they can have a future. And of course there will be some contradictions to this. For example Toyota says we are not much into this; there is also Alfa Romeo who says we will never be engaged into this, because the joy of driving is the main reason why people buy an Alfa Romeo, but of course they should do this, otherwise their share values will fall. Still, apart from them all the others are heavily investing in this technology. So the question is, which are these benefits? I think the first answer is that it will not be that costly to be a driver. There are a lot of discomforts involved in driving. You have to keep your eyes on the road, to be concentrated; you can't do anything else. Your newspaper and social media have to wait until you' re at your destination. And since you have to be concentrated you tend to be more tired when you're arriving. So when you can take your eyes of the road you tend to diminish these discomforts. And I think this is one of the leading consequences in this field. We also know – studies have shown – that around 90% of all car accidents are related to human errors. So the question is, what happens if we take the driver out of the equation? Because maybe there will be other faults, like systematic ones, of software. But still there is a huge potential [with driverless technology] that there will be a decrease in the number of accidents. So there are two major benefits that you can see. You want to drive safe and you want to get there with as less discomforts as possible. Scheduled AV tests, like in Aalborg/Vesthimmerland will take place in specified roads, times etc; that is level 4. It's another story if we say that level five goes not on specific routes but from your point to your wished end. That is a whole other question. And if this is possible we will see some things much more dramatic in my view. It will change the ownership structure, probably also the [unhearable] structure. It will have a huge impact on how we see mobility. And it will be more or less just mobility as a service instead of car ownership and so on.

Pauses (...) refer to the times when presentation of data included in the appendix take place.

What I've done in my analytical approach is that I've been very very conservative. And when I analyze this area I just rule out the level five possibility. So which are the benefits if we only can get to level 3? What is the magnitude? Just to get some numbers, because this area is difficult; it's very difficult to get a full image of the benefits of going to level five automation. This is because I'm an economist and what we like to do is to make separate progress analyses; so all the rest equal analyses. So you change one thing and all the rest remain as we know it. The problem is that with level 5 and with a fleet of cars driving around it will be nothing like the picture we see today. So the analytical structure kind of collapses. We have to change the analytical way of thinking in order to get an idea of the benefits in that scenario. So what I've done just to get an idea of the possibility I've looked a bit at level 3 automation. And I've tried to make some pretty simple calculations on what would be a conservative estimate of the benefits for consumers if we get a 100% shift to level 3 automation. And I've gone through the lower cost, discomforts and accidents. And what I've seen is that combining these two can bring a benefit of 20 bn DKK annually in Denmark, when it's fully implemented. (presenting data from presentation provided in the appendix part X). Predictions come from the government [Danish Road Directorate (Vejdirektoratet)] and according to them next year we'll have a market introduction of level 3 cars. (…) Level 3 is where you are free to take your hands off the steering wheel but when the car tells you (sounds etc.) you should be able within a fairly short period of time to take over the control of the car.

G.K.: How much will this period be?

M.K.: This is a big question. Is it 10 seconds, 20 seconds I don't know. There's a problem with people, not getting fast enough into driving mode. You have to orient yourself, which are the other cars behind, what is the environment before you are ready to take control of the car. So it actually takes a bit time for the brain to get into this driving mode. So it's a good question. I think it will be a part of the competition how long you'll have to take over control of the car, how frequent the taking over will be, how often can a car decide by itself etc.. (…). I think government (vejdirektoratet) will first take driverless cars into motorways and in more complicated roads (urban environment etc.) later on. And that will probably be an idea of what is the right way for the car; you have to collect data, to find out in a very standardized environment what is the optimal reaction from the car. That is why guys from Vejdirektoratet say it should be highways first and there will be some years when they will collect data on car's reaction etc. before they are allowed on ordinary roads.

G.K.: Which are your concerns and challenges that will mixed traffic face?

M.K.: That is a hard question. It will be for sure harder to introduce these cars as long as there is mixed traffic. That would be an additional problem. I think something like autonomous driving will only be possible in an environment where all traffic is autonomous. Because there are some other benefits (e.g. driving in shorter distances) and I think you'll never get the full benefits of autonomous vehicles as long as there are ordinary vehicles out there. For example, some highways have two lanes now but in the future you could easily have them with three lanes in the same place. But you have to have a full implementation of AV to see these benefits. So there are some of these benefits from AV that will not be seen until the last manual car is over. We are already speculating because there are some unknown elements in this equation. Because how will the politicians make it? Will they make dedicated lanes? I don't think they will but I don't know. Will at some point say you can't go on a highway if you drive a manual car? We don't know. It's possible when we reach maybe 95% penetration of AV that it will be optimal to make it [ban ordinary cars from highways]. It's really not on me to say what politicians will do when we get to that point. We could go now through the basics from my calculation on how AV will be deployed. This is from something that I have presented earlier (…). It shows where are we now, which is a kind of level two – partial automation - and then comes conditional automation (level three) which will be introduced next year. (…) Here the driving discomfort cost in Denmark is shown, which is 120 DKK per hour. Here you can see that discomfort cost for travelling by train is 23% lower than driving a car. Then I say ok, in a train you can do more things like reading a book or even go to the toilet. You can't do that in a (level 3) driverless car. So I just make a plain assumption that maybe cost is not as lower to driving an ordinary car as travelling by train; maybe it's just half of it. However this is just an assumption; you can't do any calculations on that. That is because actually we have no studies in the world saying something about it. (…). One thing we know from socioeconomic analysis is that for every accident with personal injury or death where a four-wheel car is involved there is an average cost to society of 5,4 mil DKK. (…). What I'm saying is that you have a possibility to introduce these cars and the benefits are real. So of course we have to be aware of the fact that there could be problems in the process and for sure we should not close our eyes that there are those technical issues and ethical issues and so on, but we should also embrace the benefits. If we just say I will not work on this technology there will be a cost. The cost will be in lost benefits. Maybe it will not be a part of national accounting system, not in GDP but it will be real. (…). And then there are a lot of things that I haven't included. I haven't included that you can optimize driving with fewer accelerations and fewer braking. This also means some environmental and positive fuel effects; road capacity savings. There's the potential to increase the speed limit and that's because when the probability to get involved into an accident decreases then the optimal car speed increases. What you want to do is to get from point A to B as fast as you want. But there is a condition; you don't want to kill everybody on your way there. So what you have is actually a balance of these two things. That you don't want to get anybody killed but you want to get there right away. So what happens is that when the probability to get injured decreases then the optimal speed limit increases. Again it's a speculation, because this is a political decision. But from an economist's point of view I would say it would be natural that if we see a decrease in accidents we should actually be allowed to drive faster. (…) There are also other things, there are some restrictions on truck drivers; that they have to rest and there are some limits on how long they can drive; there are some regulations on that. Maybe it's not necessary to have these regulations. So there will be like a truck platooning (…) so maybe you could save 2/3 of truck drivers. This is about some of the benefits of going from level three to level five. I haven't done any calculations on this but this is just to get a feeling that what we see now would not be optimal in a level five world. This is a pretty normal car in Denmark [showing a conventional private car], but if you look at it it's far from optimal in a level 5 environment. So what we have here? We have a single owner car, so there are a lot of consumers who have a lot of their savings actually tied up to a car for maintenance etc. So there's some cost that can be saved. If you also look at the traffic and the commuters, often there is only one person in the car. This car, even though it is used for commuting every day by a lot of people, it is actually built for a weekend, for a holiday situation. It is built in order to have the whole family, your skiing equipment etc. It's not built for that situation [commuting]; It's really not efficient. How much time of this car's use time will be the situations where it's necessary to have it? Not much. So it's not optimal .It's quite heavy and this is because it's built to cope with an environment where there's a high chance to collide. But what if the probability of getting into an injury decreases dramatically? Then it's maybe not optimal to have such a heavy and rigid frame. Then there's a whole issue of how much time you use this car. A study says it's about 4% of car's lifetime that it's actually used. So there's a huge potential of using the car more instead of having them parked down here. And the last part is that you have a car where you have to have a driving license. Not everybody has one, (like children, elderly people). So maybe we see something like this [showing a level five car]. What we see is (I don't put money on this but just to illustrate what we're talking about); In level 5 you can actually read the newspaper. Maybe you can play with your kids on the back seat and so all sorts of things. So the cost of driving drops even more. (…) Level 5 situation will of course influence where people want to live. It's not super clear in which way it will go. There are some who say that the cost of driving will decrease, so it will be less costly to live hundreds kilometers away from work and commute to there. So maybe we'll have a more dispersed population. But there are others who say it will not be like this. (…) They say it will be even more attractive to live in the city centre because congestion will increase. And congestion will increase because traffic will increase. So which one is true…maybe it's the second.

G.K.: Will the state take some measures in order to prevent unlimited travelling, travelling without any purpose or support a kind of (driverless) public transport, like buses, metros etc?

M.K.: I am sure that the metro, S train system will be highly highly efficient because that is how people get to their destination in another way. That will be very very important in a more congested future with AV. Again I'm speculating but I would just guess that road pricing would go even higher in the political agenda. You haven't seen many countries, if any, at the moment who have been implementing road pricing. But of course, if we can have cars driving around using a GPS and orienting themselves in the environment then we know enough about them to be able to implement a road pricing in the city. So I think that would be one of the measures. And then I think maybe there will also be optimizations, [deriving from] from the [possibilities of] AV. You have this phenomenon of hyper-congestion, where traffic demand in a road exceeds supply. (…) What about when we have a level 5 situation? If we can say that we program the cars that if you are at this point [about to have hyper-congestion] then all cars are directly diverted to other roads. There are huge huge benefits. Reduction of parking spots is also a benefit. Traffic police: What will traffic police do if they are all level 5 cars? Is there really any reason? Parking costs, driving schools no more. Part of the collective transport maybe and some of the police; How can a robber get away if there are only AV? So parts of the police can maybe also cut. And of course these former policemen can do other beneficial things for the economy. Road capacity also, maybe some energy efficiency, cars will avoid hyper congestion and even congestion, by getting to other – not congested - roads. And then I haven't even mentioned the company side of the situation. Saved salaries, the thing that often when you buy something you have to buy a lot because it's costly [to transfer the stuff to the company's place]; you have to get a driver and what if the driver is not there? What if you have to buy 10 pencils instead of a thousand? Why not saving the storage costs and all the financial costs having money bound in your warehouse? And agricultural machines. We've seen an agricultural revolution. 50 years ago it was a lot of the population who was employed in the farming industry and it's been decreased from 50% to 4% or something. But why do we need a person doing the fieldwork? Maybe not. I can't do any calculations on that because it's a whole other world. But the benefits are clear over there. In my view it's not like this potential will happen for sure. It's a bumpy road getting there; Maybe even getting to the point where you get the full benefits of level 3. It will be troublesome too. But what I would like is that people instead of going on and on and on about the ethical problems – you probably already know there's discussion about a driverless car driving over the old lady or the child, where there's an ethical problem that you have to programme; and who decides then who gets killed. The people who tend always to go to this discussion tend to miss the greater picture. That the situation where a car will actually have to decide whether to injure an old lady or a child will be fewer, because most accidents will not happen. So it's kind of – let's not get stuck into a theoretical ethical discussion where what we're missing is that a lot of children and a lot of elderly people will actually not lose their life. So that's one of the reasons why I thought that when we talk about AV we miss to have some numbers that show some of the potentials. That's why I did this project.

G.K.: How about the political willingness so far to implement AV and which are your thoughts about those decisions – the political stuff?

M.K.: I think so far there has been a quite positive attitude towards this area. Both the former and maybe especially the new minister of transport have embraced it and stated clearly and loudly that this is the future and we have to get ready for it. There will be trials. The legislation that says you are allowed to make trials, like in Vesthimmerland and elsewhere will be there in July. So they will test it and that's a good sign. What I fear a bit is when we'll see the first kind of accidents how will politicians react. Because there's a danger maybe that they will overreact. If we have a car accident where an AV driving over a little girl or something I don't know how the politicians will react; I'm not sure about that. I think that there's a real chance that they will be overreacting and kind of - maybe not putting a stop but - putting a delay in their implementation. But again I'm just speculating.

G.K.: Did Tesla accident bring any discussions about safety of AV here in Denmark?

M.K.: I think there were some discussions but I think that – again I'm guessing now – it was to me pretty clear that this car was not a level 3. So the driver just had never to let the car driving by itself. And he was told that, when buying that. I think that was included in the dialog [about the accident] and that was the big help. Because if this car was sold as one that could for sure drive on a highway with no problem then maybe reaction would have been harsher. I found it quite interesting that American road authority that made a study with the statistics of Tesla showed that Tesla had decreased the number of [its] accidents by 40% because of the different software (LKA etc.); and all those solutions that will be a part of an AV. Actually we are not at level 3 yet and it's very very promising if, already at level 2, accidents have decreased by 40%; That's huge. We don't know yet but this is a situation where people are driving but the car at some point takes control because if it sees an accident is happening in front of it, it will break. I find it very interesting.

G.K.: How about the society, is it ready?

M.K.: And will it ever be? I don't know and I think probably there will be some adjustments in people's view of it. I think the first experience we have with one of these cars will make us more familiar with that. And maybe it will be a provoking the first time or just letting the car drive by itself, but hey, we have metro where there is no driver either. So there's a lot to get used to it Maybe these people will have a hard time in the future because maybe they will not be able to enjoy their car. Then there is another big issue. How will the insurance market be a part of it? If for instance you can get that if you drive an AV you are not responsible for almost all accidents? If that will be the case, then the insurance premium on ordinary cars will increase substantially. Because if something happens it will probably be the fault of the manual car or of the driver of the manual car. So, who covers the cost? Maybe the guy in the manual car. So maybe it will be a big gift, coming from insurance companies, but I don't know. That could be a scenario. Because some people say we'll always have manual cars.

G.K.: In July will we also have insurance regulations to incorporate AV?

M.K.: I don't know but I'm sure that in Vesthimmerland and other areas where AV will be deployed in trials the authorities will demand that AV will be properly insured. This maybe could also be calculated with insurance companies; they get some publicity saying "we are insuring that because we are safe with them", I don't know. There is also much branding in this field. You want to be a first mover in this field and I guess the insurance companies are interested in knowing where this market is going. Because if I'm right about the big changes that will happen especially in the ownership structure in the car market if we get to level 5 automation, a big part of the AV owners will be developers. All the consumer-oriented car insurances will be gone. So they have to find out how to insure these cars in another way, or just lose their whole business area. It will be interesting to see. Maybe they already know how to react and they just don't tell; they're companies' secrets. But they have to find some other solutions, otherwise they lose a big part of their business. But again, will that happen? Will level 5 ever be on free roads, where you'are just able on an app "hey, come get me"? I think It will be very interesting; and many things we say about mobility as a service [will be realized]…that will be it. Nobody wants anything less than to be transported from their location to their wished location. If you can avoid congestion, you want to do that without stops on the way. And I think that will be the limit in the city; that everybody will want to do this, so a lot of people will go to trains, metros and so on to avoid getting stuck in congestion.

G.K.: Do you think that in places that where AV projects will be developed, like Aalborg, Vesthimmerland, Copenhagen etc., these projects will rebrand these areas as innovative, open minded or efficient?

M.K.: I don't think you'll attract car industry just because you make a trial with an autonomous bus. One thing you should maybe have an eye on is that these small factories, which cut down the design phase, I think from 8 years to like 1 year – which is crazy - maybe could actually result in making Denmark again the car manufacturing country. I don't know how big chance there will be for this, because we have Germany just in our backyard and Germany has well developed car business. Maybe there is a chance, I don't know. And of course it will be interesting for some of these [AV manufacturing] companies to collect some data on what is working and what is not working. But why should you want to place a car factory [at the test field] at a moment where this data can be sent to whatever part of the world you want? This is my view. I could maybe overlook something; I don’t know. But I had a hard time seeing from a business point of view what is the case just because somebody says “you can try here”. Then all places which are trying this technology should have this factory. I think they don’t have. So maybe that is the wrong reason to try this technology in my view. There are a lot of good reasons finding out which are the prospects of this technology also for the municipalities. You can make transport of disabled people more efficient, you can save bus driver’s salary in regular routes and so on.

Abstract of the content said after the recording was stopped

- Speed limits will be differentiated in a fully driverless era, as, since there will be no human driver in the equation, they will not aim at the avoidance of human fault. In particular they will be shaped on the basis of how probable is an accident to happen, given the characteristics of the spatial environment (street width, turning radius etc.) and other conditions (road surface wetness etc.).
- Driverless cars may be able to identify road signs as human drivers. Experiment on if driverless cars are able to detect road signs took place a bit before and 98% of road signs were successfully identified by the vehicles.
- Driverless cars will not need any new infrastructure in order to be rolled out on the streets.
- Advantages of driverless cars will be the main driving force in their implementation. Deployment of this technology has more to do with what people want and less with political power or willingness.

Dennis Lange, Legal Advisor, Federation of Danish Motorists. Interview at FDM headquarters in Copenhagen on 31/3/2017.

G.K.: Would you like to talk about what you think here in FDM about driverless mobilities?
D.L: Generally I ‘d say that we are positive on autonomous and self-driving vehicles, they are gonna coming and no question about it and it’s not, we don’t try to stop it or have anything against. But our main concern is that autonomous and self-driving vehicles are coming and they are welcome but they should not come in a matter where road safety of every other car or cyclist or pedestrian or whatever is compromised because of the autonomous vehicles. So we all have to be on the roads at the same time and we have to be there safely.
G.K.: I understand. So which are your main concerns about autonomous vehicles?
D.L: The main concern I think would be that this autonomous self-driving mini bus, for example... that will be put on the roads is very slow… 17km per hour or something like that. And that could be an issue for the other cars on the road; they are not expecting someone so slow driving at the road. So that could be an issue there; and of course these self-driving vehicles have to fit in everyday traffic without making any accidents or dangerous situations or whatever. And I think it would take some time for all the other cars and cyclists and pedestrians and so on to get used to see a self-driving vehicle out in the real road; and you know, learn how to interact with them safely.
G.K.: Which actions are needed for this to happen?
D.L.: I think the legislation that allows trials; that ‘s the right way to do it at this point. We have to learn more about it and have to see how this will affect the real world, how this works on the roads. So, I think the approach of studying with trials is the right decision instead of just, you know, letting every AV to move around us.. And, as we read the legislation, there are also some thoughts about the safety issue. There has to be the essential; who will make sure that the trial isn’t unsafe and so on. We think that at this point of time that would be the right way [to roll out AV on public streets]; to make sure that we have some kind of control of all of these trials. And then perhaps it would be necessary to, you know, invent some certain signs you have to put on inside these areas, where the trials are run or perhaps make these vehicles more visible with, I don’ t know, a light on the roof or some marking on the back or whatever thing, so the others on road can see the vehicle...
G.K.: In the transition period it is said that the driver of a driverless vehicle will have to take control of the vehicle in case there is an emergency situation; but do you think that is that

possible? I mean when you ‘re driving for an hour and everything is fine, is it possible to get the control of the vehicle within some seconds in a critical situation?

D.L.: I think it would be very difficult to gain the control in a matter of seconds; that period should be quite long actually. I think I have seen that the safe is a couple of minutes or three-four minutes before everyone can safely do that. So saying that in a crash the driver has to take the control in a matter of few seconds I don ‘t think is the safe way to go; It is possible to go wrong in some way. There is not anybody actually who know the true facts but, when you see some of the accidents that have been with the Tesla cars in the U.S. for example, the one that had overseen the lorry going accross, I ‘m not sure you could argue that the driver had one or two minutes to actually react to but didn ‘t. I don’ t know, when you ‘re driver in a car, that you expect is doing all the work and suddenly you are in a situation when you have to react now and I think it would be very difficult. It would be dangerous to make that moment; to make a system where the driver has some period of time to actually gain control when is needed.

G.K.: Which are, according to your belief, the benefits of self-driving vehicles?

D.L.: Of course there are multiple benefits. The one benefit that especially brought make us talking about the conditioned sentence that you can probably get these vehicles to drive closer to each other. Therefore you can have more cars on the road; that would surely be an advantage. The difficulty is whether this impact would be in full effect before every car is autonomous or if it could have some effect when you have both autonomous and normal cars on the road. I guess... Of course one of the other benefits is when you ‘re sitting in a autonomous, or more is a self-driving car, you can do some other things, than just pay attention to the road. You can rather have a sleep or read or watch a movie or talk to your fellow passengers or whatever. And I think that would be, of course, a benefit that has some value in the time you save; in the time you are able to do something else. Whether all people at all times should do other things in autonomous vehicles; I ‘m not totally convinced about that. I think today some drivers even though are behind the wheel paying attention they actually do that and, I don’ t know, relaxing at the same time or in their mind they are not worrying about the job, the wife at home with the kids and whatever. You have this, you are sitting in your car and your paddle wheel, you are paying attention to traffic but you don’ t have to worry about all the other things in your life. So would that be different when you are

in an autonomous car I ‘m not sure if you ‘ll use your time, I don ‘t know, to write an essay or call your boss or whatever. I ‘m not exactly sure about that.
G.K.: So you are also worrying that this time, this spared time in the car would be spent in doing things to stress us a bit more.
D.L.: Yeah, that ‘s a risk. Some say that this is one of the main benefits; that you are working in the car. But does it actually mean that instead of now, that you are typically working eight hours a day, you ‘re suddenly working ten hours or twelve hours? That might be a benefit for the boss but not necessarily for the person in the car.
G.K.: Exactly. Do you have any concerns regarding congestion from the increase in mobility that all people would be able to drive a car, to get a car?
D.L.: Yeah, without a doubt yeah. I think a couple years ago, when everybody started talking about autonomous and self-driving vehicles there was this understanding, that it would solve all our congestive problems. But, since then, more and more had actually, you know, thought about it deeper and come to realize that, well, elderly, handicapped people, children suddenly have the ability to take a car; more people with the need or the possibility to get in a car and get out on the road. And I can’ t see it, in other way than that we can see more cars on the road and not less. So, yeah, I think actually that autonomous vehicles and self-driving vehicles will result in more congestion if we are not doing anything else about, e.g. on the infrastructure, ...than just putting those cars on the road.
G.K.: What could be done in order to avoid the congestion effect?
D.L.: I guess, I think there are probably two main issues, main things you can do. One is you have to adapt the road infrastructure to this scenario. You can imagine that, I don’ t know, if you take the motorway up here, it is three lanes in every direction. In the same state it would be possible to cram even more cars when the are autonomous; you don’ t have to expand the road but you would have, I don’ t know, four lanes perhaps, because the cars can drive closer to each other. Perhaps that’s possible, but I don’t know, you would probably have to build roads or expanding roads. That’ s a possibility.
The other issue, the other thing is that there is some chance that the autonomous vehicles and self-driving vehicles would be this kind of - I don ‘t know, mini-buses or some car-sharing - benefits that it’s not every person in their own car but you are sharing cars more than you do today. I think it’s difficult to predict whether that would be true. I think the other reason that the cars; the private cars today are social success is that a lot of people actually want this

ability to be themselves in their own little box. And no one want to be with three or four people they don't know, and I don't know, they don't want to talk to if it 's not necessary. So I'm not convinced that we are all gonna be in a car-sharing thing. I think there is still the desire to be on your own in your vehicle.

G.K.: Do you worry about the art of driving that will be somehow lost from this event?

D.L.: I think some people would worry about that. Total generally speaking, I guess we have two kinds of drivers in the cars right now. We have those who drive the car because they want, they like it, they think it's funny in some manner and then you have the people who are driving the cars because they have to; they don't have any other alternative to get to work, or school or whatever. I think those who are driving today, that really don't want to, would love to have another opportunity; this would not be a concern to them. But for those people who like driving there is absolutely the risk that this ability to have that kind of fun [of driving] will be missed. One could say that if on some point you are not able to get behind the wheel and drive your own car, then those people who have enjoyed that they would be missing this opportunity.

G.K.: What about legislation? Trials would be allowed in Denmark in the following period I think, but what about the ethics, liability concerns? What' s going on here in Denmark?

D.L.: Well, if we start with the liability question, I believe as well as the driver in the car actually has control of the car, then the liability should be handled the way we do it today. You have to be liable for your actions. But, when you are in a self-driving or totally autonomous vehicle and you don 't have any possibility to take over the control, then it's not the driver or the person being in the vehicle that should be liable. It should be, I don' t know, the car maker or the car owner, or whoever put this service out on the road. The liability should be with them. It wouldn't be wanted to make someone who has no chance of doing anything else in the situation, make them liable.

G.K.: Which do you think will or should be the approach when the cars have to face a kind of trolley problem?

D.L.: I don't have the answer on what the solution should be but we think that the decision about how the cars are going to react in a situation like that; I 'm not sure it's the car manufacture who should take this decision. That should be done by governments or EU or something like that on that level. Someone has to at some point decide how do we handle a situation like that, because it 's difficult, provided there is not one right answer. Everyone who has an answer should speak. But you have to, someone has to, address this chance to make some kind of decision on how we are gonna program these cars to handle a situation like that. I think that would be one of the great difficulties about the whole autonomous car issue.

G.K.: Is society ready for these cars in general?

D.L.: In general I think yes, but society is not ready to, you know, put a switch on and every car has to be autonomous tomorrow. We are not ready to that, but I think we are ready to seeing these vehicles on the roads in tomorrow scale and then up scaling over time. I do think that, yeah. I'm sure that some people, I don't know, are afraid of or worried about this progress, but on the other hand, some people are looking for this future. Generally, I think the society is ready. It' s not something...this looks to be the future. I think that society will adopt it over time, as to so many other developments over times. So, yeah, I don't see that as an issue but it has to come gradually and I think that it's by nature that will happen gradually. You don't have that switch to pull on ant you have another future tomorrow. But I think that, yeah, that's not in our concerns.

G.K.: If you were taking the decision on the time period required to go from this point-level 1 to the 100% level 5; if you were the global minister of transportation which period would you choose as the transition phase?

D.L.: To the point where every car is a level 5 car? When you talk to people some say that in five years every car would be a level 5 car. I don't think that's true. And then on the other hand there are some saying that there gonna be at least fifty years before that scenario is true. I'm not sure that's true either. I think that reality is somewhere between those two arguments. Here in Denmark the average lifespan of a vehicle is somewhere between fifteen and seventeen years; so the cars been sold today are to live out on the roads for fifteen-seventeen years. So there is gonna be some kind of assessment period before every car has been made to a level 5 car because these old cars are still living. I think that before we have the scenario with every car being a level 5 car, my guess, and that's really a guess, I think twenty five to thirty years. I think that would be some more realistic but it could be quicker than that.

G.K.: Do you think the technology is ready now? If we were in the scenario that we would like to establish 100% driverless mobility in five years, do you think the technology is ready to do that?

D.L.: Honestly no, I don't think so. As far as I'm informed, nobody has been able to, at this point, produce a true level 5 car; a car that can drive itself in every road, on every condition, every day of the year. I think the path from the point we are know that some cars can drive themselves in ideal conditions to this point where it can drive on every condition every day and so I think this path is going to be the most difficult; to develop, to make the technology. I don't see the true level 5 car around the corner. This is gonna take some time yet I think. I don't think that technology is ready as it is today and I don't think it would be ready in five years, ten years perhaps. But yeah, you know it's all difficult when we are talking about the development of technology because you can't actually predict its course.

G.K.: What about the other effects of driverless mobility apart from safety and congestion; for instance about the space in the city, what do you think?

D.L.: Well, I think it's more than obvious that one thing our cities can may be different than they are today. For example, parking spaces would not be of the same kind of necessity as it is now, because when your autonomous vehicle has driven to home, or work or whatever, it can drive out of the city or drive to the next assignment. So we don't have the need for all these parking spaces in the cities anymore and this space could be used to, you know, something else, buildings, recreational areas, I don't know, parks, something. So it will have some impact on how we built our cities, how we design our cities and so on; no question about that.

G.K.: Do you think that applications of driverless mobility now, like in the case of Aalborg and Vesthimmerland, will act like a branding symbol, like it will make the local community look more innovative or stuff like that or have maybe any development effects; to attract more modern business or something like that?

D.L.: I think that, if you welcome driverless vehicles or driverless technology in a bigger scale at some area on the country, I think it's quite possible that would draw other kinds of businesses and knowledge to that area and you can, you know, make some, I don't know, some kind of civic value for autonomous cars. Where that would be or what we have to do to make that effect, I don't have any answers for that. But that could definitely be a result that, you know, skilled people with a lot of knowledge on one field, tend to, you know, stick together to be...on the same area where there is the possibility to pursue those fields and those skills.

G.K.: So, which is your vision about future mobilities?

D.L.: How about the time spent, in how many years ahead?

G.K.: You can tell me about the evolution of mobilities.

D.L.: I think that over time in the future we will see mobility, the process of mobility, more as a service and not as much as owning a car, a bike, a bus or whatever. It will be I don't know, when you get up in the morning and when you have a car, a car-sharing car the last mile for example, and the next day it could be another configuration on how to get from your point to where you are going. There are always some minor developments, some minor steps in that direction and I think that we are gonna see more of that. It's my guess, but I don't think that the idea of owning a car , your own car, is going to go away for some years, several years. But, you know, one thing doesn't eliminate the other. It's totally possible to still have your own car and for example use it in the weekend to visit your family or whatever, and then in your daily commute to use the mobility as a service idea to get through the city. So I think there would be some time where a great variety of mobility ideas or concepts will exist next to each other and we will, as persons, all people use those different types of transportation depending on what our purpose is or what day of the week it is and so on.

Nikolai Sørensen, Deputy Chief Executive Officer, Northern Jutland Transport Authority NT. Interview at his office in NT headquarters on 7/4/2017.

G.K.: First of all would you like to tell me something about your involvement, in NT, in the Aalborg driverless bus project and with driverless buses in general?

N.S.: NT has the responsibility for all the public transport in this region and we are working with buses and trains but also demand-responsive transport. We take care of special transport for elderly people, handicaps, people going to the hospital and so on. That's the area where we work. We have a strategy; we make a new strategy every 4 years and we're also having a strategy for 2016-2019 and we can say AV are not a part of our strategy [until 2019]. But it has to be a part of our strategy somehow; but we don't know exactly when the right time is to involve us deeply in this kind of politics. But of course I know some of our partners Aalborg Kommune have the project at the Astrupstien and we also are involved with some skills and some more issues but responsibility for this project is Aalborg Kommune. But we take part in the project. But in the next year I guess we have to take action in some strategic considerations about AV and we have to find out how we can involve these cars in our strategy we have today. That's where we are right now.

G.K.: Should we implement driverless mobilities?

N.S.: Yes of course, because they will give us some advatages in our ordrinary public transport system. But it depends on how you implement the AV. And i guess if you look it from top you have two possibilities like this. *[drawing a schema with the following]*. The one is you say AV is just a private issue. It's up to you and your family and your colleagues etc.. If you want to have a driverless car or not. Then I guess we'll end in a situation where we have many driverless cars. And that will give us some big problems with queues; it will not be easy to get around and you'll not be able to optimize the use of the car. In the other scenario I guess is that we have some regulations in this. So you use these AV in a shared fleet combined with Public Transport (PT). And that is of course our point of view in this. And we have a strategy here. In fact we have two strategies. We have some big cities in our region and between those cities we have a very efficient public transport network. We have buses, trains and very high speed and a lot of capacity. People who live here *[showing big cities in the schema]* have a lot of of PT. Maybe they also have cars but they have all they need, in fact.

Our problems is we have a lot of people in rural areas and these people do not have PT. And there we have a strategy that we have a big fleet of minibuses, taxes and so on.

G.K.: You are talking about Flextur/flextrafik?

N.S.: Flextrafik, exactly. And we have a contract with about thousand vehicles in flextrafik so we have made a planning system where it's possible to, through rejseplanen [trip planning application of NT] that you put your address, you say you want to go here and then the planning system will offer the customer a trip from the rural areas to the public transport network with a taxi or minibus and then you can go further by bus or train. So actually with this system we have the solution that involves all our area and all the people living here. So this is our strategy that we invest in these corridors here with better and better PT and better and better trains with higher intensity and many buses and then we shut down some of our routes we had in the rural area with low demand. We had buses, routes here but we hadn't got any passengers; so we were just losing our money. So we shut down these routes and used our money to this, called plustur and to invest in the main lines. So that takes us in this AV concept because we now have the infrastructure with our Demand-Responsive Transit (DRT) sending people to the main routes; so if we could change these vehicles [those operating the DRT] to AV then we have a very efficient and cheap way to get people to our network and that could be we have a better business case in those routes [DRT], because we have a bigger area where we send the people. So if we can use AV as feeding to this network [the main one] then it would be a very good business case for us we think. We have not figured it yet, but it could be. And it will also solve a problem because you can share these AV and who will gain from this ? I think, we can have a proper PT system that is cheaper and more efficient, while in the bigger cities you have a situation where you can decrease the amount of cars. Cars are getting a lot of space in urban areas; and spaces [parking space and so on], especially in Aalborg are very expensive. And maybe you can use this space for public parks and so on so. Actually you can have a more efficient PT system and you can have higher quality of life in the city. So I think that's the dream I guess. But we do not have any specific plans at the moment. I guess in near soon we have to integrate this concept and this mindset in our strategy.

G.K.: I'd like to make a parenthesis. Which is the difference cost for the passenger among the taxi service you offer and a bus ticket?

N.S.: In our strategy the price you pay for this taxi is PT price. So you can take this trip for 22 DKK, but our cost for this trip is about I guess 120 DKK. So we have to put some money in this gap. But exactly the money you put in this route [feeder to the main network, when it was made by fixed bus service] was even bigger than that. So we save money because we shut down these routes here [bus lines - feeders to the main network] . But I don't think we have an accurate mathematic on this because we have implemented that in a period of 10-15 years. So we have taken it step by step.

G.K.: How about people's reaction, acceptance of this system [DRT]? Did people prefer it over the former situations [fixed bus lines]?

N.S.: In the beginning the politicials and also the citizens were worried about we had to shut down these routes and we had a lot of discussion in our papers and so on. But on the other hand we could see that this system we had before didn't work. And the ones who were complaining about this system were actually people who used their own cars but some in a while, when they need the buses (once/twice a year), they would like to have the bus. But we couldn't have a bus going 10 times per day 365 days per year in those services; it was so expensive. So when the time was going there were more and more acceptance about this system. Today we have about a hundred thousand trips per year but today these trips cost a lot more. These trips cost about 50 or 60 DKK with the tax and ticket system we have now. From January next year we'll implement a new system, with a price of 22 DKK for any trip, so it will be a lot cheaper to take this. So I think when we implement new system we'll go from 100.000 trips per year we'll have now to about 200.000 trips per year. But let's see… It will be exciting.

G.K.: How about the timetable of this service? How is it coordinated with the main line services?

N.S.: It's very easy to make a trip, you can just book it in the app and app coordinates this trip with main line buses. So when when you hit the bus you'll have a maximum waiting time of 15 minutes or shorter. But we guarantee that you'll come to the bus sooner than the bus has left. We have two different systems that coordinate with each other. So we have a big IT system that manages all this thing - for the whole country it's the same system - but we are the first we take this step here. And I have to say we are also nominated to UITP award, which is a global public transport organization, in this category small cities and less dense areas because of this project [flextur]. And we’ve been working for this for 10-15 years. So it’s been a long trip up to here. We hope to win.

G.K.: I hope you win too.

N.S.: Thank you very much.

G.K.: How about the success of this system, flextrafik, here in Aalborg? When did it begin?

In Aalborg it’s not that a big success because in this system we have now, because flextrafik fares are 2+ times higher than the bus ones.. We have a system today where the cities, the Minicipalities, can choose their own fares. Municipalities can decide if fares are 3,5 DKK per km or 5 km 8 or 12 DKK. And a lot of our cities and Municipalities in the rural areas have decided a very low fare but the big city Aalborg has chosen the high fare. So we don’t have so much flextrafik [use] here in aalborg, because it’s a bit expensive. But when we implement out new system where it will cost 22 DKK for any trip it will be much cheaper for people in Aalborg to use it. This service will be a new product, plustur.

G.K.: So it will also be 22 DKK to move by flextrafik inside the city of Aalborg?

N.S.: We don’t know yet, because you have Aalborg Municipality and you have the city. And I guess they are going to decide a fare system where you can travel to/from a rural area to a lower price 22 DKK but inside the city of Aalborg you’ll not have this offer. So here you have to pay this [12 DKK per km]. In the city there are many buses so it’s not necessary to have it [plustur].So i guess it will bet this system here in Aalborg Municipality.

G.K.: Which is the difference between flextrafik and flextur?

N.S.: Flextrafik is the ”umbrella” with many different products (flexhandicap etc.) So we have flextur, we’ll get our plustur

G.K.: Together with flextur? Why?

N.S.: Because the products have some different advantages. Plustur is optimized as a feeding route to the PT network with high service to make sure you’ll not have to wait so long to the buses. And you an only use the plustur from a rural area and to the PT network. You cannot take a trip from your point A to point B; you can only go to the bus stop to take a bus or a train. But with flextur you can take this point-to-point service. Flextur is actually like a taxi service. But this here [plustur] is a bus service. That is the difference. If you look at our fare system, this [flextur] will be the expensive trip, but with high service, actually taxi service; and this trip here [plustur] will be low cost but you have this with a bus or a train trip. In the flextur, which is a taxi service you can decide whatever you want. So this fare system is the flextur [3,5/5/8/12 DKK per km] and fixed price goes with the PT fare system.

G.K.: Do you think there will be any alterations in the decisions of the municipalities about the pricing?

N.S.: I think so. Because when we introduce our plustur we think our municipality [Aalborg] will higher the prices on flextrafik. We have a lot of municipalities today that have the low tariff but I think when we have plustur they will set the prices up for flextur. So the system is if you taking a flextrafik to a bus or train you'll have it cheap and when you use it as a taxi service it will have to be more expensive. That will be the mindset.

G.K.: How about the political stuff in this transformation - when rural bus routes were shut down? For example which was the reaction of taxi drivers?

N.S.: First I have to explain that we have flextur, plustur and we also have we call it Flexhandicap, which is a taxi service for handicapped people. We have something called flexpatients, that is for people going to the hospital. So in Denmark if you're going to the hospital you'll get free taxi service to the hospital, that is our law.

G.K.: Regardless if it's emergency or not?

N.S.: Yes. We have a lot of different flexhandicap/patient etc but all these services is something that is paid from the state. From about 20 years ago we started a system that we started to coordinate all these trips. In Northern jutland we have 1,6 millions trips per year from elderly people, handicaps, people in hospitals and so on. And the situation before was if you're going to a hospital or if you're a handicap you could just call the taxi and then send the bill to the government and get paid back. And this was extremely expensive. So about 20 years ago we decided to coordinate all these trips, so that it would be a lot cheaper. And we also planned the system so the drivers and drivers' companies had to give us a price; a low price. This is because there is competition and we have a system where we use the cheapest car; so if you have a cheap car we use you a lot and if you're expensive we don't use you. So all the taxis are giving a price to us and then we coordinate all the trips and then plan them; so you can have a 3,4,5 customers who will be planned to be coordinated. So instead of sending 4 cars we're justing send one. And then we put the other out to taxi every minute. This system we started up about 20 years ago and that gave us big trouble with taxi companies; they lost a lot of money of course. So today we already have taken the battle with taxis. And today everyone has accepted this that we have planned. We started up as the first in Denmark about 20 years ago and today the whole Denmark is using this business model here. And they're also using the same system as this [DRT]. So flextur and plustur actually have not given us problem with taxis because we have taken the problems earlier.

G.K.: How much is the percentage of drivers' wage on the expenses of flextrafik systems?

N.S.: We can see the prices we get from all our cars where we have public tenders. It depends on the vehicle, but it's around 300-400 DKK per hour.

G.K.: Is this the final price including driver's wage, fuel etc?

N.S.: Yes this covers all of the expenses; it's the price we have to pay for the vehicles. And I guess driver's cost is 210 DKK per hour, so it's about 2/3 of total price.

G.K.: If it's not an individual driver but a company operating the service, let's say Dantaxi, how much is the profit company gains?

N.S.: I don't know. In your example Dantaxi company is like an "umbrella" again, where they have some independent companies under them. Dantaxi has IT system, booking system; if you call a taxi they have a call centre to take the phone and so on. But all the companies under dantaxi have their own cars, own drivers. So how they split the money to the owners of the cars/companies etc I don't know.

G.K.: So it's maybe one or two companies intervening between driver of the taxi and customer; which also get some share.

N.S.: Yes but 20 years ago we only had dantaxi in Aalborg so that was a problem. They could set the price exactly as they wanted to. Now we have contracts with all taxis in the whole region. So if we have to, for example to make a flextrip from here to here we may not use one company if they'are too expensive. We'll use another one.

G.K.: That's a great system and I really hope it will also be applied elsewhere. Because phenomenon of empty buses in rural areas is rather common, and does not offer that much.

N.S.: Exactly, and we have last mile problem, if we have to get some passengers in our network. So and that is I guess our strategy in the future. To replace this taxi service of lost rural with AV, and maybe also the buses, but I don't know. Let's see what is the future, I don't know. And I don't know when the future actually will happen. Is it about 5 years, 10 years that we'll have these AV…So we are thinking about when is the right time for us to involve us in the new things.

G.K.: Taking into account all features of AV, like legislation, social acceptance, technological readiness and stuff like that, could you make a speculation on when we'll see driverless cars in Northern Jutland, for the last mile problem?

N.S.: I'm only guessing, but maybe in about 10 years? I'm only guessing, I don't know. But we have a big advantage here because we have the planning system. We have the IT system that can make the global coordination. So actually we only miss the cars… We just have to have the cars. Of course we have to make some IT integration and so on and that is very difficult, I know that. But maybe it's possible in about 10 years, maybe. Maybe in some closed areas we could bring it…

G.K.: Like Astrupstien?

N.S.: Astrupstien is also built in this mindset because you have some areas here at Astrupstien with a lot of elderly people and maybe some also social classes that do not have their own car and so on and we have some good roads here and here *[showing Humlebakken and Universitets boulevard]* and then we have university here and here we have a small bus station [for bus lines 11 and 14]. So for AV the right way is to combine this bus here so that you can get the people here to the public transport network. Actually it's the same mindset that you have a driverless car to integrate it with PT. And you can make some services in all the area there. Because for these people that are living here *[showing the area between Humlebakken and Universitetsboulevard]* maybe it's too long to go to the bus stop here and too long to go to the bus stop here *[showing Humlebakken and Universitets boulevard]*.

G.K.: And it will also continue up the way to Saltumvej?

N.S.: Yes, let's see. Now we have to make this project and see, how does it work? And our role in this project is only something about the signs and...how to explain now

G.K.: Is it about the interaction between cyclists and the bus and stuff like that?

N.S.: No, this is Aalborg Municipality that is trying to do that. We have another planning role in this project. We have nothing to do with the planning and the IT system and so on. So you can say it's a pilot here and we've not IT integrated it to our PT system yet. But I think if the pilot is going well I think we'll have to do that. So we can integrate it with Rejseplanen [trip planning mobile app], so you can book your travel using the app - that could be very nice - and maybe also you can pay with Rejsekort. So but that will happen later.

G.K.: Do you think society is ready for AV? Or will it be ready in the following years?

N.S.: Yes and no. Because it's very new now so I don't think people or even the politicians had really thought about the problems this new hill can make but also what advantages there will be. They had not the political discussions because everybody is so focused on the improvement of technics and where this is possible, but they are not discussing what kind of problems it can give. So I think that people say it will be nice and will give us some possibilities but the problems have to be discussed at some point. So I think that if the citizens are ready for AV or the politicians are ready for AV it is something they don't know yet actually. Because we have to discuss what the consequences are.

G.K.: Could you state some of these problems/consequences?

N.S.: For example, there will be too many cars, if cars are going to be cheap. And we've seen that in the last years. Today you have to have a driving license. In the future, with AV, it will not be necessary to have one. You can increase the amount of cars of course, if children, elderly people, everybody has a car. So the problems about queues in the cities will be huge. So that is one of the problems. Of course you can also have problems with the unions; drivers' unions and so on. But there are many other advantages of course, with driverless cars. For example it can act in a positive way too that people who don't have driving license (children, elderly) can drive; and if you share the cars you maybe can reduce the amount of cars by 80% maybe. And that will be very fantastic. But if this is going to happen there has to be some political discussion about what future we want to have. And not just say it's the car companies which decide, because the expenses, the costs, in road, pollution and so on will not be paid by the car companies. So they have to find the money for them.

G.K.: Which is you vision about future mobilities?

N.S: This is that we can combine AV cars with very efficient public transport network. I think this is our vision. And maybe the whole system is without driver. That is possible.

Mette Skamris Holm, Head of the Department of Traffic Planning and ITS, Aalborg Municipality. Interview at the Administration of Urban and Spatial Planning of Aalborg Municipality in Aalborg on 7/4/2017.

G.K.: First of all, why is Astrupstien chosen for his project?

M.S.H.: I think we have a lot of infrastructure which could be used in a better way than today. It is located in an area where we have some people that might be not so mobile and public transport today is not so good. That’s why we think this path should provide a much better connection; in the future also with +BUS our BRT network.

G.K.: Is it a part of a greater regeneration project?

M.S.H.: The trial is not just to test the technology. It’s also to test how are people looking at this kind of technology. Can we integrate this kind of technology in an area where people feel connected with and protecting this kind of technology? Can we also engage the youth? Do they have some kind of responsibility to take care of it instead of destroying it, painting on it and so on? There are a lot of different kinds of elements in the test. Then of course in a larger scale we’d like to see, is it a kind of public transport, that we can transfer to other areas here in Aalborg? Also because in Denmark wages are a very expensive part of Public transport. So of course this kind of technology is still expensive, but its going so fast manufacturing this kind of vehicles, while data transfer will not be so expensive. It’s electric, still it will be quite expensive to use electricity; there are different rules when you use it on a train, than to use it in a vehicle. We are trying to push this legislation so they remove a high part of taxes on the electricity of public transport. When they take taxes away it will be cheap to have electricity for public transport, so I think it will be a competitive mode where we don’t have the expensive wages to run this kind of transport; and I think it can provide a mobility particularly for young and elderly people. That’s the kind of the trial.

G.K.: You said it is a trial. Will it be continued?

M.S.H.: Legislation that is now; the national law about his system says you can apply for a 2-year trial, but there is a possibility to prolong it. It can go for up to nearly 4 or 5 years.

G.K.: Which is the legal framework for such trials?

M.S.H.: There is law – an amendmentto the current law – in the national political system saying that it will be allowed from 1 July to do this kind of test with this kind of vehicles. We are still discussing a lot of issues with the ministry of transport about traffic safety issues on the vehicles, surveillance of the vehicles, how or where will the vehicles engage if it's something wrong in the vehicle, because we will apply for a test where we do not have a person present in the vehicle and that is a bit ambitious actually. So we should provide a lot of confirmation about different situations. For example if vehicle stops but doors do not open, who will be there, or how long it can be until a person is there to open the doors of the buses. Or will it be something it can be done through the surveillance system, where we have people sitting behind screens and looking at everything; for example can they push a button? How are they going to respond? Text says vehicles shall have mirrors, but does it make sense? So there is a lot of huge and minor issues about how it will be done. Law says we need an assessor [for the test] but the people who are educated to be assessors come from the railway industry, which is another technology; other security issues. So there is a discussion who is it that is going to assess our project and put a stamp this is clear this is not clear and so on?

G.K.: Which will be the role of this [mobilities] service? Which kind of land uses will It connect?

M.S.H.: It can be a broad group of uses. We have several destinations along this path, stretch is 2,1 kilometers. This is what we'd like in years *[presenting the plan of the stretch of the second phase, included in the appendix]*. To connect the whole Astrup path with BRT, so that the people leaving along this path can take the +BUS and go to the University hospital or to the city centre. When planning the whole project about Aalborg East and having all discussions with related stakeholders (developers, University, real estate companies etc) people leaving in those residences said they would like to have public transport nearer to them. However when it [driverless bus idea] first poped up most people were laughing. They said, no It's never gonna happen. Path also serves health centre, where possibly some not so mobile people will want to go.

G.K.: You said some people that might be not so mobile leave here. Which mobilities restrictions do these people face?

M.S.H.: Along this path man elderly people leave, that might be no so good in walking, especially in long distances. There are also disabled people in institutions around there, young people that should be transported to the school; and their parents may want them to be safer and put them on the bus. So I think we have different groups of people.

G.K.: Is it an area with low car ownership levels?

M.S.H.: Yes it is actually. It has been for quite some years some of the lower income groups of people that are living here, so car ownership is also quite low. So by providing different kinds of modes [of mobilities] to the people we are also medicating low car ownership. That's why we around the city are also making better conditions for the cyclists, we create +BUS system. I also know housing companies which have put in car sharing concepts, so through our rent you are also able to book a car. Therefore there are different modes provided to people out there.

G.K.: Could you make any speculation on when full driverless vehicles will be on the streets and when we will have no drivers at all?

M.S.H.: This test is level 4. And I know the discussion about driverless situations and about cyclists and pedestrians, who you cannot actually control. You will be able to control other vehicles and I think the technology to build information out in the roads or in the cars, can be done. How it will actually connect the pedestrian and the cyclist; because you cannot connect information between a vehicle and a pedestrian. That is one of the issues actually. This test might also give us the information about the interaction [of the bus] with pedestrians and cyclists. Because they will still be part of it. You'll have the bus, you will have the cyclists and you'll have the pedestrians. So, when you only have vehicles in the streets I dont' know how long…It also depends on the regulation, how quickly they want to outphase old vehicles, that are not able to be part of this system. I know we are often surprised on how quick things go. I don't know. I think in 2040 we are here there. I have also heard speculations for 2060/2080 but I think it will be quicker; I don' know. But I think "driverless" boats/ferries will be here sooner than cars. Now they are testing "driverless" boats in Holland to transfer people and they are thinking of bringing those boats also here to make [Limfjord] connections even better.

G.K.: In how many years from now do you think "driverless" boats will be introduced?

M.S.H.: Five maybe. But legislation we have for that kind of means is worse than the one we have for trains. We are still part of EU and a lot of legislations also come from different kinds of conventions or EU laws, so that’s a bit “heavier” system to control. Buy maybe we can make some trials as well.

G.K.: Why do you think we should implement driverless mobilities, in general?

M.S.H.: I think It provides us first of all a new type of mobilities. The first one we are making here is not so flexible, but we can make it more flexible. We can make it so that people can use an app or something and then have their vehicle at their door within 5 – 10 minutes or something like that; at least in a small system like this. We could have one bus actually going to people who are not able to walk, pick them up from their door and make them a logistic route. That could be a phase two of this trial in a few years, but that’s what we’ll decide when we’re prolonging trial for two more years. So I think this kind of technology will give us a better option to use existing infrastructure we have. They use lesser space, they can pass each other in very little space, we don’t have to have so wide roads as today and we can get much closer to people than today. So I think we can have some good options that vehicles we have today are not able to provide; and maybe also cheaper. As a piece of equipment is very expensive, but it will probably become cheaper. As our mobile phones and other technologies eventually became cheap I think it will be the same kind of development in this type of vehicles.

G.K.: I can see cyclists are on the same path

M.S.H.: That is actually the idea because we will have something flexible; the space will be flexible. So when we have two buses passing each other cyclists will be behind one of the buses and when bus has passed cyclists will again have this space. So there is a kind of flexibility in using this space.

G.K.: But how will cyclists “coordinate” with buses’ movement?

M.S.H.: For now it will be the buses that are coordinated with cyclists. The bus has cameras and sensors outside it, so it will see if cyclists are coming. So if cyclists are not moving behind this bus the other bus will stop. If bus sees it has a free path then it will pass. And of course this will be interesting because we’ll see how polite will cyclists be. They may be so polite than when they see a bus coming they move back, for the bus to pass, we’ll see. Otherwise the bus will stop and cyclists will pass.

G.K.: How fast will buses run?

M.S.H.: Speed is not entirely decided yet, I think we'll start at 20 km/h, then 25 then 30 km/h, because maximum allowed speed in this path is 30 km/h. But this kind of mobility is not designed, as it is here, to be high speed. It's not the purpose. So if it will be able to run about 25 km/h it will be fine.

G.K.: Are there concerns about driverless mobilities? If yes, which are they?

M.S.H.: It's a new technology and it's always interesting when you have data that on how it works. We know from mobile phones, when sometimes connection goes down. And this is of course a risk for this kind of technology. So if connection closes, of course then bus will stop. Then you need to test surveillance systems; if they can identify weather situations. There is also a risk that other people do not respect it, e.g. spray on its sensors. Because it's not working in case its sensors don't work. So it can be impacts from humans, from weather then it's the technology.

G.K.: Do you think technology is ready for that?

M.S.H.: Yes I do think it's ready, otherwise it would be too risky. But in this project what we have actually done is to minimize the risks. It's not running with other vehicles or in public roads. It's still a path. And it is not running that fast; 25 km is not so fast. In that sense we have minimized the risks, compared to running it somewhere in the city, among other vehicles.

G.K.: How about the acceptance it will gain by the society?

M.S.H.: People were more reluctant before a few years than they are today. In 2014, we were asking them "Could you imagine that you would you drive with this kind of the bus where there is no driver?" and most people said "oh yes, I would do that?". I don't think they could exactly imagine what they were saying yes to, but they were willing to do something even though they did not have exact image of it. And I think today you may find even more people saying yes, no problem. Because you see often in the news today about this technology and its progress.

G.K.: How about the transition phase; when ordinary vehicles will run on the streets together with driverless ones?

M.S.H.: That is the most difficult part. [Autonomous] vehicles will act more quickly than human drivers - our time of reaction is longer - but I think the phase where you have driverless vehicles interacting with ordinary ones with people behind steering wheel is the most difficult phase. And I actually think people sitting in the old vehicles, driving, is the part that you cannot control. We are still humans. You can see it in the accidents we have. Many accidents we have are people-made. So we can try to control all other matters; to make vehicles more safe; to create better roads but we cannot change people's minds. So I think it depends whether you from national or European side you say we want to phase out old vehicles within two years, for example. So then we go fully driverless in certain roads for example, like motorways, and people have a very short period of time to replace old cars. There is also a lot of job to be done to get all the information driverless cars will need, to adapt signaling and many other issues.

G.K.: Drivers in semi-automated vehicles will partly rely on automation and possibly perform other tasks during driving. Do you think they will be capable of taking over control of the vehicle when needed (e.g. to prevent an accident) in a provided time period of e.g. a few seconds?

M.S.H.: That's when accidents happen today; when drivers are doing anything else than driving. I think in the transition phase we might see an increase in accidents actually. That's why I think we should implement it in phases. For instance it's allowed to have it fully driverless on the motorway, but when entering the city you should switch to manual mode.

G.K.: Are there any discussions about amending Vienna Convention?

M.S.H.: They are trying to interpret in a different way. Words do not say that physical person should be present in the vehicle but there should be a person that could act here now. That's what we find interesting in our trial. We are having persons sitting in surveillance centres, just not in the vehicles. And they are acting from the information of the vehicle; or what they can see on the screens; or if some of the passengers are pushing the emergency/stop button. And that is what we want to have approved. We are still having a person that can interact immediately, but this person is just not present inside the vehicle.

G.K.: What about liability and ethics of driverless vehicles?

M.S.H.: I know a lot of factors on that. Actually different insurance companies have set that this technology means that insurance rate will be cheaper. Because they can see the traffic safety is much better in this kind of vehicles than what we see today. So, for parking for example. It can park much better than I do. And the discussion now is if something is wrong and the vehicle causes an accident which is then the responsible part. So this is the center of discussion at the moment actually. Or if a pedestrian is walking in front of this car and it does not stop.

G.K.: How about decision making in critical situations? In the example with the old lady and the child, for example [describing the example].

M.S.H.: These things are being discussed at the moment, e.g. who will be hurt in this case, the old man or the child.

G.K.: Do you think we'll go the way of private driverless mobilities or shared ones?

M.S.H.: I think it will be most beneficial if it's shared one. I don't know what we will do, as human beings. We still have generations that like to own. The young though, from what I see today are more likely to share things than the elderly. And you still have some who want to have control of the vehicle themselves. Because they have a very sound willingness to control their things, or they want to speed or whatever. But I think that might be some kind of sports. I think it will be most beneficial if you could share it. Because why would I have a car in my garage standing in the most of the time? When other people could have used it?

G.K.: Are there any variations in the extent of AV acceptance across different parts of the population, based on e.g, education background, gender, etc.?

M.S.H.: We don't know. This is one of the things that we want to try. A lot of people have told us how on earth could you say of implementing a thing like this in Aalborg East? They ruin anything and so on. This is one of the things also University is involved. That is the test. How we can give young people and the people in this area a connection to this. It's no sense in putting this kind of mode in the western part of the city Hasseris where people have very very expensive cars and things like that. They are not going to use this kind of transport.

G.K. Making Aalborg East residents having a sense of ownership towards the bus would be great. When I was in Aalborg East, the screen of the bus stop I used was damaged by a cigarette; maybe it’s the only one with such a damage in Aalborg. It will be great to make the bus a “part” of the society.

M.S.H.: Indeed it would be very important. We actually thought of having some of the professional graffiti painters to paint the buses.

G.K.: That’s great

M.S.H.: Yes; painting the whole bus by a professional graffiti. Because usually when you have these professional people, what they do is they respect it. No one will ever bear to take their own painting. So that’s one of the thoughts we have. That’s one of the ways that may could get some respect to the vehicles. We also may have a competition giving the buses names, or use paintings, colours etc. So actually people feel that this is “ours”, “We are first movers and things like that”. And I think usually when you give people an option they didn’t have before they are more grateful to take it. If you do these options, let’s say to people in Hasseris they will say ok, even thought they are the first movers. But if you could give people this option in Aalborg East, where they may not have a possibility to be so mobile they might say that’s nice. Now I can easier go to the shops than I do today. I don’t know.

G.K.: Which is your vision about future mobilities?

M.S.H.: Actually my vision is painted in a latest mobility concept that people are able to move on the transport mode that suits them in the moment they want to use it. That’s actually my vision. Today it’s not always possible for people to take public transport because the stop may not be close to them etc.. If we have a system it’s easy to use; you can for example be picked up by a small car and then travel then on a fast train or bus – because that’s feasible, since people want to go everywhere - it would be great. So it’s easy for people to make a choice. That would be the best. We’ll still have problems with capacity in our roads. We have congestion, because people will still drive and what you can see is we have congestion in the morning and in the afternoon that people come back from their jobs. But you can see trips are increasing during the day. People are travelling more and more than it has been in the last many years. So that is still a need for people to get around. People sometimes say, public transport will die, nobody will want to run the public transport. But I think that’s wrong.If public transport is a possibility to move fast - because that’s what people want when using public transport to go from home to work and it’s easy - people will still use public transport.

Odysseas Raptis, Chief Executive Officer of E-Trikala SA

Christina Karaberi, Member of the Department of Research and Communication of E-Trikala SA

Loukas Vavitsas, Project Manager of E-Trikala SA

Interview at E-Trikala SA headquarters in Trikala, Greece on 22/3/2017 [own translation from Greek].

C.K.: Regarding the evaluation of the project, It was a 6 months pilot project where 1400 questionnaires were acquired, as also noticed in the evaluation report. In some of them passengers had to describe their own opinion of the project; some of them had to do with how drivers evaluated the project, their interaction with the bus concerning safety and other features; and some questionnaires were sent by mail (to people throughout the city) regarding not only the bus but also their overall perspective on autonomous driving. It was rather interesting to gain an insight on how people envision driverless mobility, its usefulness etc. We've also created a scenario where we sharply reduce car traffic in the city centre – which is a primary problem of the city – and we provide citizens with the possibility to park at four points in the outskirts for free and then be transferred to the city centre by driverless buses. We conducted a cost – benefit analysis for this scenario, elaborating on various economic indicators, and Benefit cost Ratio was overwhelmingly positive, even without including non-quantifiable benefits, such as an improvement in urban environment, positive tourism effects etc. For me this is the main outcome of the project. Personally, I would approach the project from three angles. First comes the technical part; how the bus lane was created, how we communicated the project. Communicating to the people "why this project" was of critical importance, as we had to make clear why we take space out of a central part of the city and to ban all parking there for 6 months; finding a parking place in the city centre is very difficult. That [the exclusion of the bus lane] was accepted by people and was adopted as a practice and supported by the people, which is very positive. Second part is the legal one, as it was a global-scale innovation, and third part is the evaluation, how it was assessed afterwards.

G.K.: Do you believe this project contributed to the establishment of sustainable mobility concept in people's minds?

C.K.: I believe it had some positive contribution. I think first positive attribute was that people saw how our city centre could be if it was like every other European city centre; namely without spending so much time and effort everyday to find a parking space. Second benefit was that people saw how much positive impact on the image of the city it had both to outside of the city [both domestically and abroad] and here, that there was a new, rather alternative service in the city. The bus was a different attraction; sight. This had a very positive impact on the image of the city; it also received rather good feedback. However the most important for me is that people saw for first time the city centre without parked and double-parked cars everywhere, being more pedestrian- and cyclist-friendly. A result of our survey was also that people were very interested in keeping those buses after the completion of the project and operating them especially in the touristic route and for night services.

O.R.: As far as technology is concerned, this [driverless] bus is not ready to get in traffic, nowhere in the world, for a very simple reason. It can't overtake. It doesn't have the intelligence to overtake an obstacle. At the moment its movement is "fixed-track"-like. In Trikala we endeavored to improve, to optimize some parameters [of the bus] in order for it to behave like a fixed-track means of transportation. Technology does not have the intelligence yet to overtake. If a garbage bin appears in front of it, it will stay there and stare at it. It doesn't know how to overtake it; it can't think. Technology has not yet solved he "overtake" issue. It's completely immature. Municipality of Singapore is about to replace their public buses with driverless ones. However we're discussing about a country where such an innovation - along with induced restrictions [for car traffic etc.] - would be more easily accepted and embraced by the citizens; it's a country where the bus will not find an illegally parked car in front of it. In a huge campus in Saudi Arabia, Masdar city, a driverless bus is also about to be introduced. In Gatwick airport, London it was the first time autonomous non-fixed-track buses operated. Under those conditions it will work.

I remember when the first meetings with the citymobil2 team were taking place here in the city and the potential of introducing this bus in the city centre came up. Most local stakeholders said no way… It took them 6-7 months, just to suggest to run the bus inside a hospital's campus (!); absolutely out of the spirit of the demonstration [to run the bus in mixed traffic]. What we did in Trikala was a venture.

Stepping out of unsafe estimations, things may evolve that fast that in 10 years we'll have fully autonomous driving out in the streets. When we began the project, European transportation commissioner told us that in 2025 in big European cities only these vehicles (AV) will move. This estimation doesn't have to do with technology but with EU's general vision that we'll have digital transportation, digital health and we'll generally be digital Europe. No way… For me it's very difficult for AV to get in traffic, at least in environments where traffic regulations are not respected.

C.K.: You can also see automation in other sectors. For instance in Sweden you go to the hospital without any paper (public health documents etc.).

O.R.: We don't know how technology evolves… Regarding the political/implementation stuff of the project; first discussion about our application to participate to the Citymobil2 project was with the subminister of Transportation. When we proposed him to bring driverless buses to Greece his question was "how can you bring driverless buses to Greece? there is no legislation. When he learned it was for experimental reasons he got more keen in supporting us and he arranged another meeting with three of his partners and us. The participants were the director of vehicle registration department, a member of the traffic regulations department (road traffic signal, road marking etc.) and one from the vehicle inspection department. It was the time of Greek presidency of EU; and a bit before the closing ceremony in Athens, where all EU prime ministers would come. Then he arranged a conference [for this issue] which was joined by 12 EU ministries of transportation. There we intended to set up a dialog on how this story could legally proceed. Because the project [CityMobil2], which was approved by EU was saying that six European cities would constitute six wide-scale pilots in driverless technology; so the legal problem had to be solved in a way for the project to go forward. Before the meeting the main "problem" that we should overcome was Vienna Convention. Vienna Convention says "car, driver…". How could the word "driver" be interpreted for the project to work? Vienna Convention is one of the UN papers with a huge number of contracting parties. Therefore when the question if Vienna Convention could be amended was arising, the other participants of the workshop were answering "forget it…we should find another way". When the meeting finally came, participants were raising more issues that should be overcome, than solutions to the existing problem. Germany proposed to make the project in the motorways and use trucks, as they already had a law that allowed this. Then somebody from the Greek team raised a question "When a driver is sitting at the driver's position, which “senses” does he/she have?” “He/she looks at the front [the road]; he has a mirror looking to the road behind the vehicle; he has a mirror looking inside the vehicle; he has a brake and an accelerator; and when the passenger asks something to him he answers”. He turned to me and asked “I read that tele-conference is among your company’s activities, correct?”. “So, can I live in Australia and work in Trikala?” I answered him yes and I was asked “Can you transfer all the [aforementioned] senses of a driver somewhere else?”. I replied “of course”. “Can you make these senses “visible” in a remote location in real time?”. I replied “I will look through it but probably yes”. So he asked the board “if we can have a driver at a different location, having exactly the same “senses” as the ones he/she has when he/she is at the vehicle, can we amend the law?”. So we had gained a good starting point for further discussion. Then, the needed bill was created and Greek Parliament adopted the law. Law was stating: driverless vehicles can get into traffic in Greece, for experimental/pilot purposes, on the condition that driver is located in a remote control centre and monitors vehicle’s movement. In each of this cases, not only for Trikala, minister of transportation should, define operation and safety conditions of the experiment with a new decree for each experiment. So we had the law. Then Trikala were chosen among big European cities like Brussels, Barcelona, Milan and so forth to become the pilot and the project was given a 2,5 km route in the city centre. EU and coordinator of the project considered it as a miracle that we can make the project in the city centre. However, when they came to Trikala for the first area inspection they were shocked, as in those 2,5 kilometers they confronted a state of anarchy. There are parked cars, trees, traffic lights and whatever you can imagine. They were not supposed to give us 2 million euros just to remove obstacles from the route. So we began the dialog on how the bus’ stretch in Trikala could be planned. But we were missing needed legislation once again. How could we take a lane out of the street for the bus? Greek legislation stats that in order to take a lane out of the street you should build a 0,5 meter high concrete curb, while the lane has to be at least 2,5 m wide. But there is no space to take 2,5 m out of the street! At the same time the intention was that the bus would coexist with the rest of the traffic. So we decide to put short orange plastic columns, like the ones Athens had once upon a time to point out bus lanes. After reaching an agreement with our citymobil2 representatives on that, we’re going back to the ministry to tell it [that we’d use the plastic columns] and the answer was “forget it”. An accident had occurred when they were in service in Athens and since then they are banned in specific road types, including a large part of the chosen route of the bus. Then we get back to the project's representatives and asked if we could put cat's eyes. In addition to the ministry's restriction we had the limitation that we could not choose any relatively tall curb, because bus' laser would recognize that as an obstacle and stop the vehicle. Bus considered anything, which was laying more than 20cm over the ground as an obstacle on its way, so the curb should be shorter than that. Moreover it should be clear that provided electronic and mechanical systems of the vehicle would assure that the vehicle is safe enough to move; of course autonomously. And then a huge concern of the manufacturers arose. They did not want to take part in the project on the fear of their civil liability.

G.K.: So the issue then was urban traffic?

O.R.: Well, you have a car which has a laser sensor and some antennas one connected with a satellite. This bus was performing the route without passengers for a month in order to record the stretch (road surface, trees, kiosk roofs etc.). At the time bus was recording the kiosk owner had the roof folded up, as there was no sun. Then kiosk owner unfolded again for some reason, but when the bus "saw" it, its system thought "something is going wrong, it's not the area I have in my memory, something has changed". Or for example it noticed that there are no leaves on the trees anymore. So its technological skills are extremely limited. It understands the environment up to an extent. It's clever up to some point. Those buses are not smart, in contrast to what we would like to say. Press and some people were calling that "gavo", which means it proceeds without looking ahead. Then we built an fiber optic network throughout the entire route with 30 access points, we connected them with the bus and we achieved, thanks to the very good devices we were equipped with, transmission time close to 0,1 millisecond (ms). That meant remote operator's reaction would happen in nearly real time. The bus was equipped with cameras, providing the same image as the one a physical driver would have as well as a remote brake that the operator could use in case it judges to do so. The bus didn't feature the last possibility, but we asked for that to be added. And if somebody was sick or there was fire somewhere etc and the operator had to stop the vehicle or tell something to passengers? We also added a VoIP telephone, which would be used for the communication between operator and passengers, if needed. On top of that we had installed smoke detectors for the case there will be fire, which were connected with the central switch that stopped the vehicle. So in case there was fire somewhere bus would stop automatically and doors would open. So what did we do? We took the driver and transferred them to a control room. There was a ministerial decree, which stated Trikala, for the 6 buses you will have there will be a control room, where there will be a driver [operator] who will have a 3rd Category professional driving license and will monitor bus' movement. I asked then, "should we really have an individual driver for each bus? How will the expected (money) savings be achieved?". And they answered: It might not be necessary but it's the first time, we're on fear, so you'll do it this way. But then I asked, shouldn't we in the future have the possibility to have one driver for 10 vehicles, or even for 50 vehicles; so that we make it economically feasible? Because even driverless trains and metros today have somebody monitoring their movement, but of course not a single person for every vehicle. I also compared it with Air Traffic Controllers, who have 200 planes on the air simultaneously. Human mind has not been surpassed yet. It would be great if, in 2050 technology will have solved problems, where computer cannot perform decision making yet and replace human brain.

So, which is our input? Where did operators take action in the demonstration? Nowhere. Bus was so silly and so "phobic" that for instance when there was an tent, which the day before was folded up but now was unfolded - and definitely did not block its way - it was beginning elaborating on if it can pass or not from 50 meters before. It was gradually decreasing its speed (from ~16km/h) even to 1 km/h (!) until it was understanding there was enough space to pass. It didn't need our drivers at a single time. On top of that when we were making any experiments that we were appearing in front of it, it was immediately breaking.

What happened then – and journalists in Trikala got "passionate" with that issue – bus lost its contact with the satellite. There were also two points on the stretch were bus was never connected with the satellite, for weird reasons. Satellite coverage was an issue. You're not in the valley or at the national road that you can easily establish connection with the satellite. It's urban environment. If an illegal VHF receiver is turned on for instance, signal can get lost. The problem that caused the incident might be a CT (Computed Tomography) scanner. It might be; we are not sure. Manufacturer forewarns bus can divert 10 cm left or right from its axis for GPS-related reasons. When bus lost connection, it started deviating. When it got out of the 10 cm safety limit, it stopped automatically. Nobody, neither the driver from the control room nor the accompanying person who was on board had the time to do something. Exactly when it exceeded safety limit it stopped; all this took place in very few seconds. And of course journalists wrote about the driverless bus which "ran over a kiosk" and stuff like that. After a month, the district attorney called us. Along with us, the president of Trikala city

KTEL (public transportation authority), who was a professional driver was also called. He was asked what would have happened if for some reason (technical etc) he was the one who had lost control of the bus. He replied if this had happened to him he would no way have had an equally quick response with the autonomous bus; he would for sure have run over the kiosk. So what does technology teach us? In spite of any imperfections it has, safety features it carries continue working. Bus stops automatically if it's not 1000% sure about its way (e.g. it stops if you approach it laterally closer than 20 cm etc.). Then you'll ask me; with all those pieces of safety equipment how slow will it drive? 5/10/15 km/h? EU commissioner, after we were chosen to make the pilot project, told me "We are waiting for Trikala to answer the following: Can the driverless bus drive at an average speed higher of the walking one?". And we proved that it can. In Trikala it was faster than a pedestrian, in spite of the many problems we had. Some people, mostly not from Trikala but from other areas, were parking in the bus lane for their ease. At the beginning we had a service car which was going in front of the bus and was alarming or honking to those who had illegally parked on the bus lane; sometimes also police intervened. As far as what you asked me is concerned, how the city accepted it, I will tell you one thing. We were beginning at 1 October. At the 31st of September in the evening I did the route in order to see if all details were ok. I was shocked! Street was full of (illegally parked) cars! I thought "oh my god, it will be a catastrophe, we will become the laughing stock of the world!". Next day at 9.00 there was not a single vehicle on the bus lane. Only a very small minority Trikala people – in most cases with political incentives to fight the project – parked on the bus lane. City completely respected bus' movement. It's a city where you can't find a single parking space, but still it respected the bus. However, what was needed for the bus to hit the streets? Registration, traffic regulation/issues and technical inspection. Vehicle should be registered and receive plate number in order to move and get insured. However vehicle was not registered at any country of EU so far as a "allowed to get on the street" vehicle and this should be overcome. Then safety regulations – e.g. stopping distances - had also to be defined from the beginning.

G.K.: How was your collaboration with local stakeholders?

O.R.: It was seamless and at the same time played a dominant role for this project to be realized. The philosophy of local authorities was to treat this vehicle like all the others, in terms of which rules should abide by etc..For example it should even have a first aid kit, like being ready to be stopped by traffic police. We had to follow whatever we were asked to do by the respective authority. In order to run this bus on the streets there had to be very good collaboration between the Municipality, traffic police, Region, local traffic management department of the ministry and us. There are some experts from Japan who have been in Trikala three times; one when we were awarded the project, one when the project was taking place and one three months ago. They can't still explain one thing; how on earth we managed to coordinate all those stakeholders and authorities. If there is no coordinator who, regardless the reluctance they face, keeps on trying, things cannot proceed. We were being sent from authority to authority in order to pick up necessary papers a whole load of times. One authority needed this paper/certification etc from another authority; we were going there and asking for it. We were trying to find the place where they would be able to certify any possible aspect of the project. It was also of critical importance that we had support from the ministry. Ministry helped us from the very beginning, where we had the discussions with EU, to when we took the number plates. If you ask me if there buses can be released to the streets the answer is no. They're many problems to be solved to roll those cars out on the streets. In an area where it is – politically - more feasible to take a lane out of the road to give priority to sustainable mobility modes you could have a vehicle like this; but it will have no difference with a tram.

Those vehicles are intended to solve the last mile problem. In the next project we are about to participate citymobil4, which is with semi-autonomous cars, there will be a charge in using the cars, in contrast to what we already did [citymobil2], which was free [for passengers]. So the question is will the project be the same as attractive as before, now that it has some cost? Because all things required for those vehicles to move have a cost, that has somehow to be covered. Another project we're planning to do now is to make urban driverless logistics. Trikala is considered by EU as a test-bed because they know if they trust us they will have the experiment done on time; having done the arranged kilometers; and completing evaluation and reports on time. So we have the reputation of a good test-bed. – It's a matter of craziness to do all those innovative things actually.

G.K.: Does it have any impact on the development prospects of the city?

O.R.: Yes, definitely, in creating new jobs, attracting high-tech companies… In May we'll have a control room with Cisco and other companies, where smart "products" will be developed (smart parking, smart cards for refugees etc.). We have also undertaken projects for digital health ("cloud" cardiograph etc) etc..

G.K.: How do you envision future of mobility, both in the city of Trikala and the other parts of the prefecture?

O.R.: Technology can bring the revolution in mobility (last mile services, Demand-Responsive Transit etc.). So our first target is to prove one person can monitor more than one vehicles. Technology can bring unforeseen benefits and possibilities in mobility, health, people's involvement in public affairs, public administration etc.. For that reason we envision to become an official test bed for technological innovations not only in mobility but in general. We aim at the added value this role will bring to the city; and we're aiming at high added value- innovation.

G.K.: So, which was the greatest barrier you had to overcome in order to bring DL to the city? (technology, legislation, social acceptance etc.)

Greatest barrier we had to overcome was the diffusion of negativism by our opponents, nothing more. We had a huge war from local media. At some point they were calling the bus "gavo" (here means something which is moving without watching ahead).

L.V.: The most complicated issue was the legal one, as we had to "cover" it legally pretty sufficiently and precisely.

O.R.: Some people were discussing about bus drivers jobs loss. Whenever technology has achieved a record, indeed some people lost their jobs, but 10 times those jobs are created in IT- workplaces. So I believe in the long term we'll create more highly skilled workplaces. Bus drivers may lose their jobs, but their children may work in IT.

G.K.: So how about the technical stuff? Which kind of infrastructure did you use in the demonstration?

L.V.: There are two kinds of infrastructure, namely what was required by the project; what we, as Trikala Municipality, had to do in order to welcome the project, which were our contractual responsibilities. It wasn't though our responsibility to create all this kind of infrastructure. All this (fiber optics, additional safety equipment on the bus etc.) is what we did to get the demonstration one step ahead. We thought "what is our philosophy? It is about to find a way to make this 2,5 km route as safe as possible and fast”. “How can that happen? We’ll have a control room, where remote operators will be located, we’ll have state-of-the-art monitoring equipment”. This is what we embedded into the project; our contribution.

Two elements that made this demonstration to stand out: First the total length of the route was in an entirely urban environment, where grandpas, children, people on wheelchairs, cars, buses and motorcycles were moving altogether. Second, it was our interventions in the experiment, namely the coverage of the whole part of the area with fiber optics, wifi and a vast amount of cameras in order to have the driver out of the vehicle. This is what was done concerning the IT equipment. As fas as the road infrastructure is concerned, apart from road markings – so that the pedestrian and the car to see that, that is their part of the road, that is the driverless bus’ part – we added 6 smart traffic lights, which were detecting if the bus was approaching and were giving it priority over the rest of the traffic.

G.K.: In CityMobil4, where AV will move around the entire city, will you have the same kind of infrastructure?

Such an IT and traffic infrastructure (dedicated lane, fiber optics along the entire route etc.) cannot be constructed for that case, or other similar cases. In CityMobil4 project, semi-autonomous cars may pass through 70 streets of a total length of 50 km. and through 30 intersections. So the only given is we will be asked to adopt a different philosophy, beginning from allocating them in the same lane with the rest of the traffic. Also these cars will be far cleverer than the one in 2015; they will be aware of how the car in front of and behind them are doing. They will be able to follow them. However, degree of difficulty will be more than two times the one of CityMobil2. We’ll have to invent this new IT system that will be used, we’ll have to configure right of way issues, to change maybe traffic lights etc.. It will also be far more expensive than the previous one; just have in mind that instead of 6 vehicles there will be more than 30. That’s why we previously talked about the potential to apply a reasonable charge to the user, maybe just to cover a part of its expenses.

G.K.: What about the IT equipment of the bus? Which kind of radars/sensors does it include?

One sensor scans the environment in front of the bus to detect possible obstacles. Then you have GPS, so that the bus can be aware of its location and if it’s on its route or it has deviated. What comes next is the aforementioned wifi equipment (the fiber optics system) so that driver’s senses could be transferred to the “driver” of the vehicle (the remote operator) at the control room, almost in real time. Apart from the above, we had a system, which was created by us, where we could press a button from the control room and stop the bus in case of emergency. Emergency switch was already embedded in the bus' system, but in order to use it first we should be closer than 600 meters away from the bus and second the bus should be in sight. In the densely built environment of Trikala city centre this was almost useless. So we had to find an alternative.

G.K.: Which will be the primary differences between CityMobil2 and CityMobil4?

L.V.: First it's the very nature of the project; namely that it's about cars moving freely in certain parts of the city, instead of buses running on a fixed route. Second it's that we'd like to have an operator who will not pay attention to the car's movement literally at all the time but when their intervention is actually needed; in other words to reduce the amount of remote operators per vehicle. If the car, when it cannot decide about something, could offer us the information "something is going on here, look at me", we could easily have one remote operator for six, or even per ten vehicles, instead of one operator for each car. It's not at all practically or economically right to have 60 operators in a control room, each one monitoring one vehicle, since in 99,9% of the cases nothing will happen. We'll see if we'll have a new ministerial decree or an amendment of the existing one. This ministerial decree is that opens all the doors for these projects.

G.K.: In CityMobil2, when was the bus running?

L.V.: We had having it for 4 hours in the morning and 4 in the afternoon. It was operating from 10.00 to 14.00 and from 16.00 to 20.00; and buses were running every 30 minutes. The route was taking 20-22 minutes.

G.K.: So it was not for commuters.

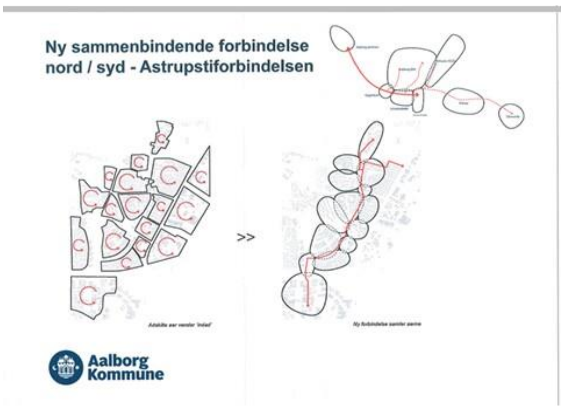
L.V.: Yes, it was not for commuters because buses were moving inside the city centre. Commuter wants to be transported from his house (in the outskirts) to the city centre, not from the centre to the centre; he/she go on foot. This service was not a commuter line; you could easily see that. Most passgners, from what I read in the evaluation reports and what I had personally seen, were students, elderly, unemployed. It's another story if it could also serve customers, who would like to go from the one part of the market to the other , 1-1,5 km away.

G.K.: Did you have somebody on board the vehicle?

L.V.: Yes, many times we had one. In the last period of the project we decided to run the bus unmanned; the role of the person on board was entirely “decorative”. He/she was sitting on the bus or pulling his hands out and greeting the people outside. The route was more of a touristic one, in general.

B. Presentations

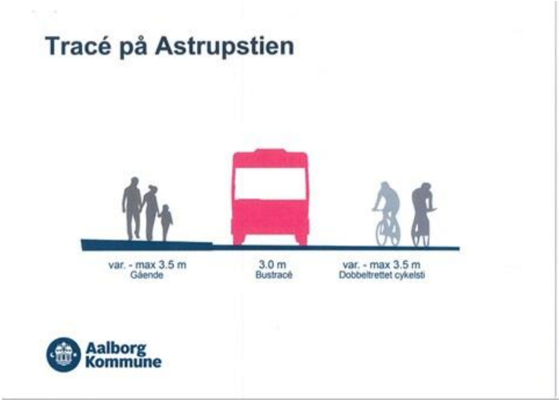
Holm, M.S. (2017b): "Selvkorende Busser i Aalborg (Self-driving Buses in Aalborg)" [In Danish]. [presentation] Autodrive conference, 23 March




Hvorfor førerløs teknologi
Sammenbinding til boligområderne
Udnyttelse af eksisterende infrastruktur
Forbedre interne mobilitet
Energivenlig alternativ til den nuværende kollektive trafik
Øget social inklusion:
- mobiliserer en gruppe borger, der ikke er så mobile
- styrke brug af tilbud i området
'First mover' ved at teste innovativ førerløs teknologi - bidrage til et image boost i Aalborg Øst
Ambitiøse renoveringer
Manglende tryghed
AALBORG ØST
Aalborg Kommune


Hvorfor førerløs teknologi
Trafiksikkerhed - 94% af alle trafikulykker skyldes menneskelige fejl – hvad nu
"Connecting people with tecnology" - Hvad sker der i mødet mellem mennesket og teknologien
Tryghed - Påvirkes trygheden i positiv eller negativ retning
'First mover' effekt - kan image forbedres via positiv opmærksomhed og omtale - kan der skabes ejerskab blandt alle = ingen hærværk
Social inklusion - Giver tilbuddet en større inklusion
8
Aalborg Kommune


Teststrækning
Visionsstrækning


Tracé på Astrupstien
var. - max 3.5 m
Gående
3.0 m
Bustracé
var. - max 3.5 m
Dobbeltrettet cykelsti
Aalborg Kommune

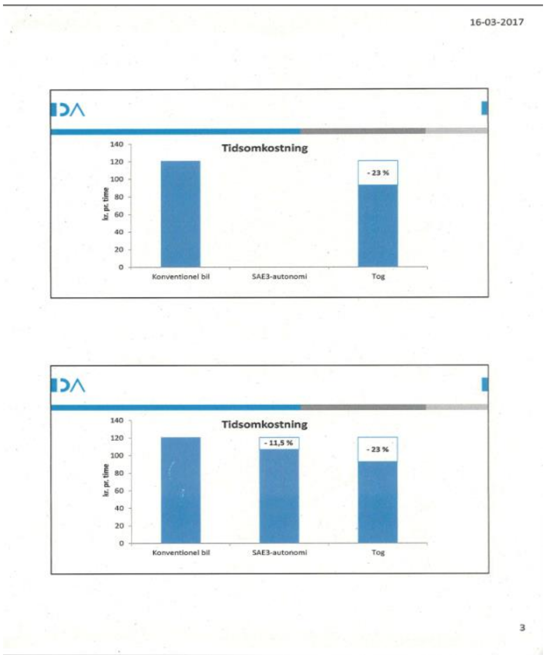

Teknologien - data
El-busser – 3 stk. på teststrækningen.
Der er plads til 15 passagerer i bussen ad gangen.
Den førerløse bus opererer ved hjælp af multisensor teknologier: GPS RTK, Lidar sensor, Odometri og 3D kamerakontrol.
Forud programmeret "GPS vej".
Stoppesteder forud programmeret.
Flere og flere modeller kan ordres og leveres - Det virker og er driftsparat.
Fremtidig tunnel under Humlebakken
Tunnelen under Smedegårdsvej i dag
Aalborg Kommune

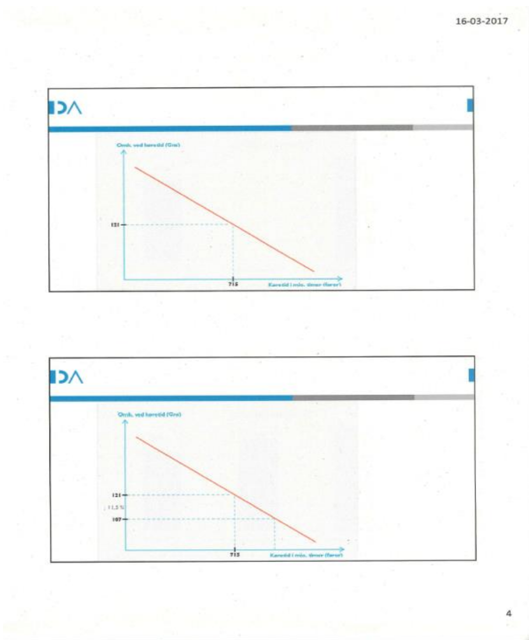

Aktører
Samarbejdspartnere
By- og Landskabsforvaltningen
Sundheds- og Kulturforvaltningen
Ældre- og Handicapforvaltningen
Skoleforvaltningen
Familie- og Beskæftigelsesforvaltningen
Udvidelse af traceet
Nordjyllands Trafikselskab
Himmerland Boligforening
Alabu Boligforening
Lejerbo Boligforening
Medfinansierer jord via Landsbyggefonden
Aalborg Universitet
Evaluering
Aalborg Lufthavn
Region Nordjylland
Aalborg Havn
Erhvervsnetværk 9220
Keolis
Drift og overvågning
Aalborg Kommune

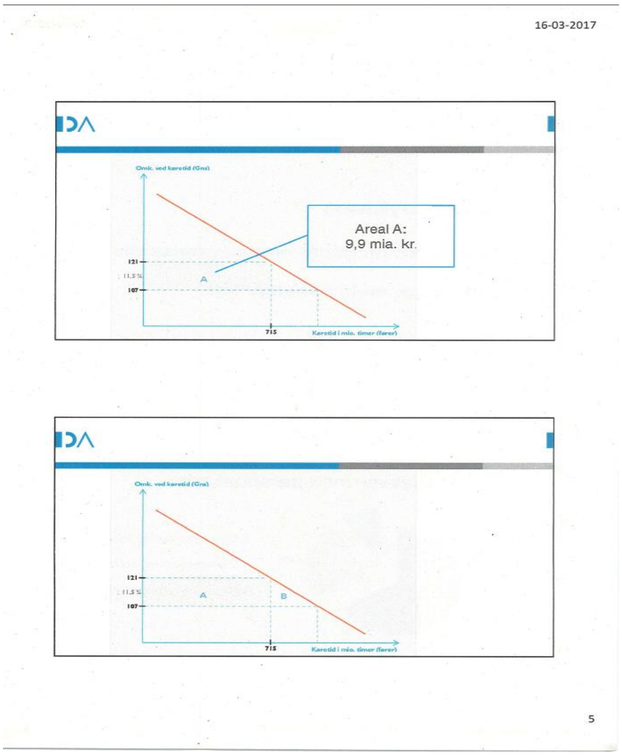

DGI Landsstævne 2017 – prøv den ☺

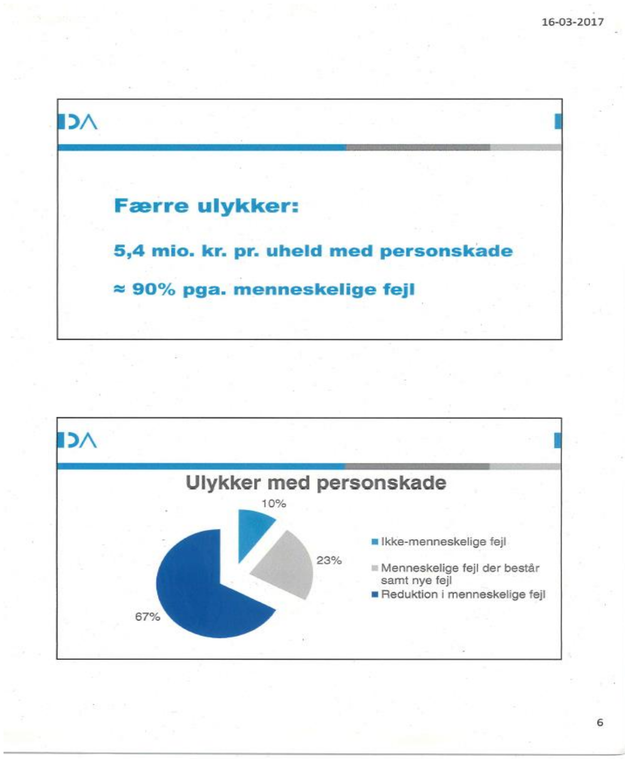

Tak for opmærksomheden !
Aalborg Kommune

Kyed, M. (2017b): “Samfundsøkonomiske gevinster ved Førerløse biler (Socioeconomic Gains with Driverless Cars)” [In Danish]. [presentation] IDA (Danish Society of Engineers].

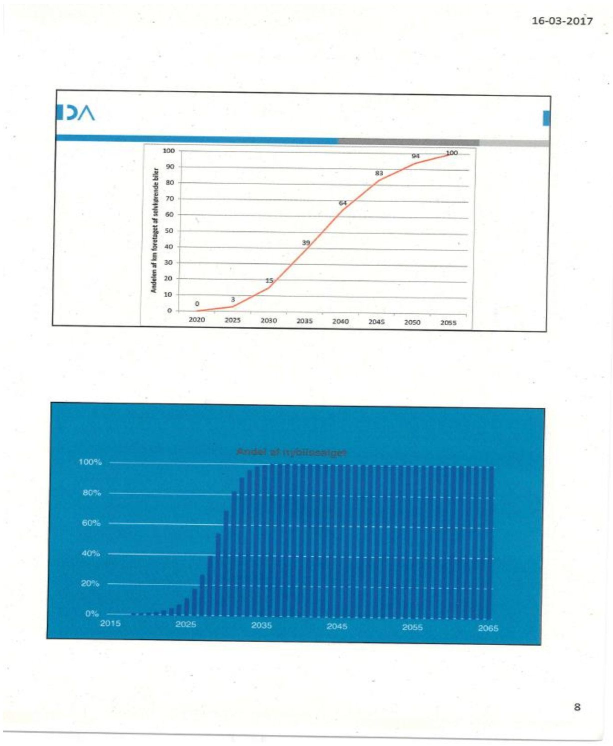




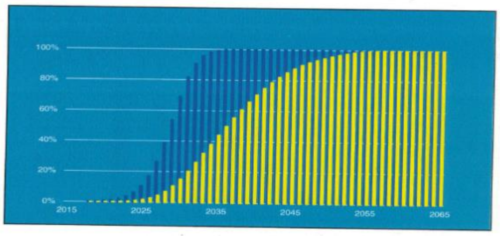

16-03-2017
IDA
Areal A:
9,9 mia. kr.
121
107
A
715
IDA
121
107
A
B
715
5

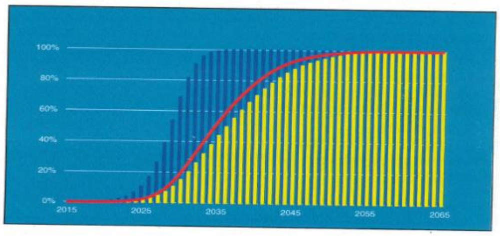

16-03-2017
IDA
Færre ulykker:
5,4 mio. kr. pr. uheld med personskade
≈ 90% pga. menneskelige fejl
IDA
Ulykker med personskade
10%
23%
67%
Ikke-menneskelige fejl
Menneskelige fejl der består samt nye fejl
Reduktion i menneskelige fejl
6


16-03-2017
IDA
5,4
2.778 * 67% * 5,4. mio. kr.
= 10 mia. kr.
2.778
IDA
9,9 mia. kr.
10,0 mia. kr.
= 19,9 mia. kr.
2 x
7


16-03-2017
IDA
0
3
15
39
64
83
94
100
2020
2025
2030
2035
2040
2045
2050
2055
100%
80%
60%
40%
20%
0%
2015
2025
2035
2045
2055
2065
8

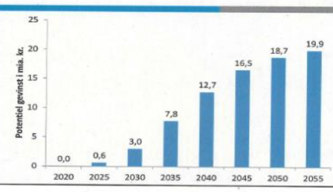
16-03-2017





9

16-03-2017



Ikke medtaget…

- Trafikvækst
- Kørselsoptimering (mindre køkørsel mv.)
- Miljø og brændstoføkonomi (Grøn kørsel)
- Vejkapacitet
- Øgede hastighedsgrænser
- Lempeligere køre- og hviletidsbestemmelser
- Platooning

… og sikkert en masse flere.

10

16-03-2017

SAE5-autonomi
- Hverken rat eller pedaler

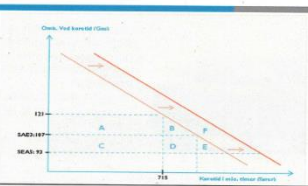
Slut med ulykker pga. førerfejl
Endnu lavere tidsomkostning

- Store kapitalbindinger og ineffektiv vedligehold
- Dimensioneret efter familieferien frem for hverdagen
- Bygget til kollisionsrisiko
- Ubenyttet ca. 96%. af tiden
- Kræver "upåvirket" fører med kørekort

11

16-03-2017

Flåder tilpasset det reelle behov?



To ekstraeffekter:
- Lavere tidsomk.
- Nye grupper

12


16-03-2017
IDA
Også bedre ressourceanvendelse
• Plads
• Bosætning
• Parkeringspladser
• Færdselspoliti og parkeringsvagter
• Køreskoler
• Dele af kollektiv transport og politi
• Vejkapacitet
• Energieffektivitet
#km/sec.
Congestion
Hyper Congenstion
#cars
13


16-03-2017
Virksomhedssiden
• Sparede lønninger
• Mindre kolli
• Just-in-time
• Landbrugsmaskiner
14

C. Visual fieldnotes and other kind of visual material

Aalborg East: "Creating a more sustainable and coherent town" (Aalborg Municipality website, 2017a, translated from Danish)

Engaging with the field

Tornhøj bus stop

Astrupstien path at its existing form

“Rest area” near Planetcentret

“Planetcentret” shopping facilities

Trekanten Cultural community center and Library

Informing local society about the revitalization project


ASTRUPSTIEN LUKKET
- Benyt fodgængerfeltet ved Sundheds-
og Kvartershuset til skolen
Tornhøjskolen
Humlebakken
Fyrkildevej
Sti til Fyrkildevej
Astrupstien
Realdania
Aalborg
Kommune
Vi renoverer tunnelen og området
ved Astrupstien for dig og derfor
spærres tunnelen under Humlebakken
i perioden marts 2017 til april 2018


AA
AA

Sorry for the inconvenience. Works are temporary but revitalization is permanent.

Mobilities and recreation joined together [under construction]

Trikala: “Aiming at [attracting] high added-value innovation” (Raptis, 2017)

Feeling the pulse of the city

Asklepiou street: Main retail street of Trikala

Varoussi old city and in the background lies the “Mill of the Elves” venue; “Mill of Matsopoulos”

Cosy pedestrian street with retail and coffee shops at Trikala city centre

Litheos river at the city centre

"You got a baby, you taught it to walk and you made it an adolescent, ready to get on the streets" (A. Alessandrini, coordinator of CityMobil2 project, addressing D. Papastergiou, Mayor of Trikala. Source: myota website, 2016). Source of photos: E-Trikala SA, 2015

Welcome to Trikala!

Building the fiber optics network, for bus' constant communication with remote operator

Technical inspection of the vehicle, like it is an ordinary car

Bus depot

First steps on public streets

Exploring the city

"After the (driverless) car"

City got a new bike lane

Though some problems still occur

Video screenshots from CityMobil2 (2016c)
(https://www.youtube.com/watch?v=pLsmsTj393o)

Buses moving around the city at day and night

CityMobil2 remote operator