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(HOW) WILL AUTONOMOUS DRIVING INFLUENCE THE FUTURE SHAPE OF CITY LOGISTICS?

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Many efforts have recently been done to partially or fully automate the driving process and make mobility more controllable and safe. In particular the full autonomous cars should free humans from the strains and dangers of driving while opening new possibilities for the experiencing of the daily life on the move. However, the importance of autonomous driving extends far beyond the mobility of persons (as drivers and passengers). Based on the review of the multidisciplinary literature about autonomous driving, the current contribution will generate hypotheses about the assessment and prediction of the impact of various autonomous driving use cases on city logistics' problematic areas (mainly Last Mile and End-Consumer Movements).

Key words: Autonomous Driving, Automated Mobility on Demand, City Logistics, End-Consumer Movements (ECM)

INTRODUCTION

In the urban areas the Last Mile relevant transportation services are performed by professional carriers such as freighters or post, producers or traders, respectively private persons who procure themselves daily goods and foodstuff [15]. Within these types the individual trips for shopping and daily errands, also called "end-consumer movements (abbreviated ECM) [07], represent an important issue because of the high diversity of individuals' resources, goals and actions. Private automobiles provide still unbeaten freedom, personal availability, space/time flexibility, and speed for them. However, the untamed growth of cars does create a variety of problems for society (Table 1). The vehicles hurrying to fetch and transport daily goods do create much stress, noise, congestion, and environmental pollution.

Table 1: Social costs of automobility versus technological solutions

Social costs of the growth of the car system	Advanced technological solutions
Traffic deaths and injuries	Traffic safety technologies: ADAS, vehicle automation towards driverless cars
Congestion	ITS for traffic control, Ride-sharing
Environmental pollution	Electric cars, hybrids, alternative fuels
Mobility barriers; no cars or not able to drive cars	Driverless cars, mixed forms such as ride-sharing

Various technological solutions have recently tried to tackle one or another of these problems; for instance, by increasing the safety of driving, intelligently reducing congestion, or enabling an ad-hoc multiple occupancy of vehicles through ride-sharing. However, broader socio-economic problems of a mobility system cannot be solved solely through technological innovation. Technical and non-technical counter-measures should be integrated in a systemic socio-technical solution for a better (more sustainable) mobility of goods. Such solution might, under circumstances, have the courage of breaking with existing models and travel on new paths.

The car system has already undergone historical changes in the ways of inhabiting the vehicles as well as in the technical configuration of cars [20]. On the background of the latest technological developments in sensors, artificial intelligence, material and fuels, intelligent vehicles and con-

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** Alpen-Adria University, L4.2.14 Lakeside Park, Haus B04, Ebene 2, Klagenfurt, Austria; oana.mitrea@uni-klu.ac.at* nected vehicles there are good chances for a decisive socio-technical innovation. Important trends in the usage patterns of the automobile have been recently observed: the use of cars seems to decline in the developed countries, young people start to drive later, cars are increasingly seen as rather appliances then aspirations/status symbols [01]. The real challenge for a socio-technical innovation in transportation (of persons as well as goods) is to move to a different pattern involving a more or less break with the current car system. This break cannot be reached in a linear perspective, but only if interdependent changes occur in certain order that might move or tip the system into a new path [20].

According to the sociology of mobility, such a revolutionary break with the traditional automobility could be the post-individual transport [20], defined by Urry as “multiple, dense forms of movement including small, light, probably hydrogen-based, de-privatized vehicles electronically and physically integrated (seamlessly) with many other forms of mobility” [20], p.33. This particular vision encompasses de-privatization, oil-independency, and IT based mobility integration.

Are there other “breaks” imaginable, particularly related to the mobility of goods in the city logistics?

For instance the delivery drones challenge the: ”traditional notions of safety, security, privacy, ownership, liability, and regulation”[14]. The germs of this break with the tradition are, according to the Rao et al. (2016): “their ability to collect data and transport loads” through which “drones are re-shaping the way we think and feel about our physical environment” [14], p.83.

The vision of thousands de-privatized autonomous vehicles (abbreviated AVs), procuring and delivering goods in on- demand basis [14] shares some of the challenges and potential of aerial drones. Also autonomous cars can be fully unmanned operated if desired. This may decrease the dangers and strains for the car occupants and free time for other activities. The safety requirements for robots interacting with humans in the public space and on roads, the dangers of an eventual connection of autonomous vehicles over Internet (risks to data privacy, criminal use), the liability in failures and accidents are relevant issues for AVs & city logistics as well. However, the autonomous driving in city logistics does have a specificity which makes it particularly interesting for the interdisciplinary socio-technical research. Originated in one of the most stable and socially accepted mobility system – the car system--, it stubbornly preserves a historical feature that will probably stay longer at the heart of the new concepts for autonomous driving: “the inhabiting of the car” [19],[10]. The cars as spaces for multiple human and non-human action posibilities on the move can have important consequences on the social, economical, technical systems and natural systems.

AUTONOMOUS DRIVING

Definition and development paths

In the last time efforts have been done to make vehicles more efficient, controllable, safer and environmentally friendlier by means of increasing automation. Various classifications of vehicle autonomy are in use, their common note being the transition from the fully manual to the fully automatic accomplishment of various functions (for an extensive review see Reference [17]. For instance, the US SAE standard J3016 includes the levels: 0 -- no automation, level 1 driver assistance and level 2 subsumed under the headline “human driver monitors the driving environment”, 3 -- conditional automation, 4 - high automation and 5 - full automation [16]. The nomenclature widely accepted in Germany includes: driver only, assisted forms, partial automation (the system takes over lateral or longitudinal control in certain situations), high automation (no need for continuous monitoring of the system by the human), and full automation (full takeover of lateral and longitudinal control by the system) [16], p.166.

The fully autonomous cars should liberate humans from the stress and dangers of driving while opening new possibilities for the experiencing of the daily life on the move. Main traits of an autonomous vehicle are: “self-reliance, fully automation, capacity to make mission-critical driving decisions” [9],p.80. “Autonomous driving in the real-world traffic takes drivers out of the loop and the driver will be free to engage in non-driving tasks from the start to the end of the trip” (id.).

A study of McKinsey Institute (2013) includes autonomous driving among the key disruptive “intelligent” technologies of our present (together with advanced robotics, cloud technology, internet of things and the automation of the knowledge network) [11]. At the presents various successful experiments with artificial intelligence, machine vision and sensors have already shown the possibility for the implementation of AV (autonomous driving) [12]. However, there is still much to be done in the field of regulatory frameworks, the winning of public support, infrastructure investments for special lanes and sensors, legal and ethical questions, or the programming of computers to make life-and death decisions [11],[12].

It is expected that the pace of technological research and development in vehicle automation will grow exponentially [18]; [2]. The introduction of autonomous driving in society is likely to occur around 2025-2028, when private consumers will start to adopt AVs [11], [12]. AV as primary transport mean is anticipated between 2040-2050 (id.). During this time there will already be several successful demonstrations of autonomous driving [16][12]. Automated busses and taxis in cities will become reality around 2026-2028 [18]. It is projected that regulation will evolve from restricted low-speed mixed forms (possibility to switch between autonomous and manual mode) to unrestricted full automation forms. New services created for partial automation driving contexts will consolidate and enjoy high user acceptance, new mobility models redefine supply chains and logistics [2]. Collaboration between important player regions will increase. The structure of involved social actors will change: new actors will become involved with the topic of automation due to new business forms and models, changes in the profile of mobility jobs and employment structures [02].

AUTONOMOUS DRIVING SCENARIOS FOR URBAN FREIGHT DISTRIBUTION

The urban areas put several challenges to the distribution of goods, mainly due to the narrow streets, the need for fast up-loading and unloading, the strict regulations and restricted access permit [1]. The operating vehicles should be small, agile, have enough loading capacity for operate efficiently, be versatile and easy to modify for various cargoes and uses, should comply with the environmental conditions and even be zero-emissions[1], p. 153.

The idea of using automated vehicles for the transportation of goods has a rather long history, even if concrete applications have been so far reserved for the delimited access in restricted areas (such as mines, port containers)[01]. Reference [01] gives some interesting examples of potential applications such as: the underground transport by means of AV from the outer city areas to the centre; the just-in-time refilling shops from remote warehouses, drop-off points for last mile deliveries at houses/small offices, waste collection and transportation, the light duty transport vehicle composed of several standardized, interchangeable and reconfigurable components [1], p. 153.

Several AV use cases with relevance for freight transport and distribution in the urban areas are presented in detail in [21], [05]:

1. The full AV with available driver
2. The autonomous vehicle on demand without driver
3. The valet parking and delivery

The first use case is closer to the present situation (current driving) and requires the active presence of the driver in the car. The vehicle includes car controls (steering, pedals, signalization, etc.) The human driving is required in more risky situations, such as when engaging on a new road or if this is crossed by many pedestrians. However, on road segments without such constraints the driving can be transferred to the autonomous robot. The route includes restricted as well as “for AV free” segments, which are either permanent or temporary. In the unrestricted areas the human driver can engage in activities not related to the control of the vehicle. The driver still has to supervise the events on the road and has a variety of intervention possibilities in navigation and operation[21], pp. 17-19.

In the second scenario the driving robot transports the passengers and/or goods (possibly also none of them) without human intervention. The vehicle is not equipped with steering wheel and pedals. The passengers can freely use and modify the vehicle interior, according to their needs. At the beginning of driving the robot learns about the destinations from the customers. The users can only decide and communicate the destinations and activate the “safe-exit”. They cannot control the car. This use case can be implemented in taxi-services or car-sharing, autonomous freight transport and even in more exotic ideas: the use of social networks to plan the routes and bring people together[21], pp. 19-21.

In the “valet parking” scenario the vehicle is parked by the driving robot alone after that the passengers get out of the vehicle or the cargo is unload. The driving robot moves the car to the desired destination or parking place[21], pp. 14-15.

The reference [3] adapts this classification to the requirements of freight transportation in urban areas according to the criteria: available driving and the possibility for free navigation. According to the author, the full AV with availability driver is economically interesting only if the accompanying person or the driver can engage during free times in value-adding activities such as preparing the next delivery in the last mile distribution, administrative works for elderly care companies, insurance agency - everywhere where documentation and administrative activities are required. He also gives an example of a precursor of the fully automated system with availability driver: in the concept of the semi-automated driving Emil it is not necessary that the deliverer gets in and out the car. He/she can communicate with a “follow-me” vehicle over the smart phone to follow him at a walking pace [03], p. 389. The valet-parking and delivery are considered difficult to implement in freight transportation mainly because of the scarcity of reserved parking places for freight vehicles with connection to a secondary road network. The perspectives for the autonomous parking and ramp- docking in the narrow inner city streets and for lighter vehicles look much more promising [03].

Flämig (2015) also emphasizes some important consequences of driving autonomy on the supply chains, mainly in what concerns the control of the vehicle, route planning, the documentation and administrative activities. Problems such as the exceeding of driving and rest times could be eliminated and tours can be less restrictively planned. The on-trip mobile work of the human deliverers can include new activities such as new route planning, fleet management, or even relaxation pauses[03].

HOW TO UNDERSTAND AND PREDICT CONSEQUENCES ON DRIVING AUTOMATION ON CITY LOGISTICS?

As emphasized by the Reference [04], in transportation and future studies the implications of automated driving are often discussed rather from a technological point of view, with deficits in what concerns its social embedding.

Sociology by contrast insists on its socio-technical nature and dynamic complexity [20] and focuses primarily on possible modifications in both social and material elements such as: ”industrially manufactured object of the car, its social meaning as one major item of consumption, its economic meaning within the involved industries, services and patterns of dwelling, its domination position with regards to other modes of movement and transportation, its cultural associations as well as its ecological impacts” [06] quoted in [04]. Newer orientations in the sociology of technology (genesis of technical innovations), human geography, transportation and policy research follow this line: the multi-phase model of technology genesis [22], the multi-level perspective (MLP) on socio-technical transitions [06].

At the present the field of technology assessment includes a variety of inter- and transdisciplinary perspectives, aiming to provide knowledge and orientation for public opinion and policy decisions about technology [08]. One key objective of classical technology assessments is to early recognize and mitigate the possible perverse (non-intended) effects of technological innovations) that can be relevant for society (early warning [08]. Conversely, the newer orientations in technology assessment increasingly focus on the genesis of technology (the early phases of innovations) rather than on effects, recognize the normative backgrounds of their assessments, and are more open to qualitative methodologies. They insist on the importance of considering the interests and perspectives of all relevant social groups (not only experts), with their own visions and emotions about the part of the problem investigated [08]. Particularly important are the early phases of innovations, the uncertainties of development; and the lock-ins of mature development phases (id).

In the current paper, the assessment and forecasting of future consequences of autonomous driving on city logistics is driven by the following questions:

1. How will a specific sector of city logistics react to the introduction of the full autonomous driving in a given use case?
2. How will autonomous driving further react to these changes in the city logistics systems through the re-configuration of its design?

Possible scenarios for assessment and forecasting are in this case: the current procurement and transportation of foodstuff and daily products by means of own cars (Current Driving CD) and the selected cases adapted from [21] and [03]: the full AV with available driver (AV1) and the valet parking and delivery (AV2), respectively the autonomous vehicle on demand without driver (AV3). We start from the hypothesis of a non-linear mutual influencing of socio-technical systems and city logistics systems, which involves the following relevant dimensions: the constellation of the relevant social groups, technology configurations, services and their performance, the processes of use in a given context, the costs/benefits/constellations of risk of this use [08], respectively the environmental, economic and social consequences on city logistics as a global system. For the representation of this hypothesis we advance the following structure and dynamic complexity of the model (Figure 2):

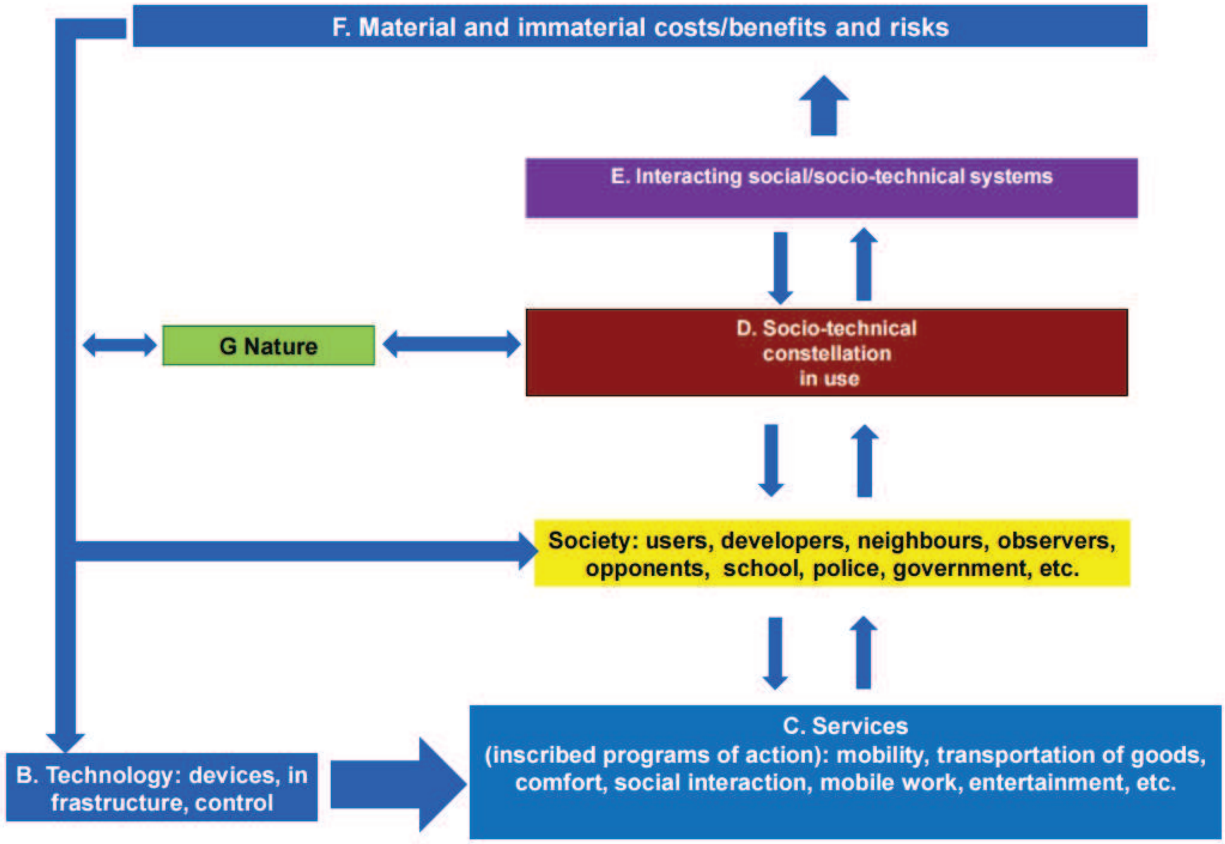

Figure 2: Architecture of the assessment model

Social actors (A): They are target users, developers, observers of technology, opponents, neighbours as members of communities/municipalities, and members of political and economic institutions, which are more or less affected or involved in the phases of technology construction, use and evaluation. It is necessary to investigate what power do they have to influence the design of technologies, their existing conflicts and cooperation potential, and if they act as supporters or blockers of a particular technological path. Often technology designers create programs of use which do not 100% match the intentions and needs of users. Therefore, it is also important to learn about the differences between CD and AV scenarios in what concerns the technological prescriptions and user programs. These differences can have impact on the design of car interiors, manoeuvring space, spatial constraints and liberties in and out of the car, the engineering of the in-car safety, etc.

The technology (B) includes vehicles, sensors, street infrastructure, traffic control, standards and protocols, software, other enabling technological systems such as telecommunication, weather systems, etc.

Services (C): The most obvious transport logistics relevant services are the picking-up of goods, packaging, transportation from A to B (on demand or not) and home delivery. More general background services, such as the integration of information flow, inventory, warehousing, and security should be ensured for the transportation of goods in both situations. It is assumed that the transport from A to B and delivery will remain key services in autonomous driving scenarios too, even if the importance of the tactical/operational driving as human activity will decrease or be completely eliminated. In the particular case of End-Consumer Movements, mobility will not be so tightly related to the strategic goals of the individuals as car owners, but will increasingly integrate the on-demand goals of networks of other users, sharing autonomous units [10]. The de-privatization of cars will increase as well as the importance of the car as a mobile space for multiple activities on the move (logistics relevant or not). In the manned transport human deliverers may perform different activities or be involved in additional ad-hoc (on-demand) services for customers. One important assessment topic is here the performance of services: How good is technology in fulfilling its promises at all Grade-of-Service levels in the given services? A performance ontology for the services in the autonomous driving scenarios has to be constructed and metrics are to be defined.

The actual use of technology (D) on a given context of city logistics is characterized by a distribution of decisions and actions on human and non-human elements to various degrees, dependent of the scaling of perspective: human-car; human-car-environment, human-car-environment-socio-politic context [13]. It is expected that the anatomy of this distributiveness differs in CD and AD at all scaling perspectives: driver-car system, driver-car-environment system as well as the broader socio-technical constellation [13].

Interacting constellations of use (E): It is also likely that the use of private/company autonomous cars in End-Consumer Movements interacts with other socio-technical constellations, such as an alternative door-to-door transportation system. The reciprocal adjustments have to be clarified.
The social constellations of risk for AV scenarios (F) will be considered after [08]: accidents, traffic system, investments, work market, access equity, privacy, and technology dependence.

The material and immaterial costs and benefits (G) of the implementation and use of the socio-technical system are for instance costs in Euro, injuries and traffic deaths, time savings, more subjective savings in comfort, flexibility, security, subjective satisfaction with the use of in-car time, etc.). The assumption here is that the structure and amount of societal costs vs. benefits differ in the CD and AD situations.

H. The natural environment will include mainly dimensions relevant for the socio-technical city logistics system such as: the air quality/environmental pollution, noise, fauna and flora.

The dynamic interplay among the variables in the model results in broader consequences for the city logistics system in use (D), which include the matters of the acceptance of AV scenarios and services by target users, their utility for various stakeholders, even the structure of the involved actors in the city supply chains. Possible changes of city mobility, consumption, disposal patterns of the city inhabitants as well as broader consequences on employment and family and work structures can also be investigated.

CONCLUSION

The current paper has taken first steps towards a better understanding of the main research fields for the assessment and prediction of the future impact of urban autonomous driving on city logistics. It has begun by revealing how some actual social trends and socio-technological innovations have the potential of transforming the shape of the current car system. The incipient decline of users' interest in cars as an aspiration and status symbol, the growing acceptance of car sharing in developed countries[1] and the innovations in intelligent car technology set good prerequisites for the introduction of de-privatized multi-purpose autonomous vehicles for the mobility of persons and goods.

In autonomous vehicles, driving as human activity often represents just an optional feature in a broad constellation of possible in-car activities. The field literature has advanced an array of possible use cases running from the mildest to the extreme technical autonomy [21]. The scenario closest to the current situation is the AV with available driver, characterized by a perpetual switch between human driving and other activities in function of the unrestricted and restricted road segments. Its utility in city logistics is given mainly by the possibility of solving additional (mainly administrative) tasks on the way. At the opposite pole of the spectrum is the AV on demand--no human driver, no steering wheels, pedals, etc. This extreme variant leaves room for creativity in what concerns the area of applications (see the ideas of underground transport, drop-off points for last mile deliveries, waste collection and transportation in [1]). It also enables a creative arrangement and re-arrangement of the car interiors in function of the temporary users' purposes.

Each AV scenario is socially embedded, in the sense that there are particular groups with various interests in its realization and range of possibilities. Users, technology designers, companies, institutions, interested observers of technological innovations and opponents are all important and responsible for the technological configuration in the scenario. At the same time technology sets limits and provides possibilities for the manifestation of needs and actions of social actors in specific services. The iterative socio-technical mutual shaping finds its stability in the socio-technical configuration in use for a given scenario. The analysis of the costs, benefits and risks of this constellation for various components and processes of the city logistics represents a key step in the assessment and forecasting process.

It can be concluded that the forecasting of the future consequences of an emerging, yet immature innovation on a given socio-technical system does represent a challenging attempt, due to the many uncertainties involved, be they of a technological, legal, economic or social nature. While the current automobility system is much researched in what concerns its technologies, services, usage patterns, and impact on society, the same aspects in full autonomous still need to be investigated. Future research is needed particularly in what concerns:

- The identification of social groups and institutions relevant for and affected by the passage to autonomous driving (analysis of involved actors required) in city logistics.
- The involved elements in the socio-technical constellations of autonomous driving in city logistics
- The costs for society if a given service constellation for driving automation emerges in city logistics

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