PLANNING FRAMEWORK FOR SELF-DRIVING VEHICLE MOBILITY TRANSITION: CASE STUDY OF BELGRADE, SERBIA

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Abstract: *Self-driving vehicles (SDVs) represent a convergence of computing, sensing, and communications technologies. SDV technology is currently in the rapid development and implementation stage. Several countries across the world are already having SDVs in actual traffic, and commercial models are expected to appear in the next decade. This disruptive technology promises many benefits, but is also facing a number of disadvantage and constraints. This research starts by identifying a range of potential positive and negative effects. Considering that the actual technological development is happening almost exclusively in only few countries, there is a need to a planning framework for SDV mobility transition in Serbia. Such a framework would enable the Serbian society to respond to the potential large risks and societal disruption originating from the SDV technology. In addition to the traditional transport planning approach, and in order to accommodate for a wider range of aspects, this research builds upon the work on technology transitions. The resulting planning framework includes technologies, infrastructures, practices, norms, and institutional and business ecosystems. The framework points to a range of state and city-level stakeholders that will be affected by the emergence of SDV technology. Focusing on the City of Belgrade, as a case study, the research develops a set of recommendations for SDV mobility transition. The special focus is dedicated to the changes in travel patterns, road capacity, vehicle ownership, mobility services, land use, safety, energy consumption, environmental effects, and introduction of automated driving zones. Finally, recommendations for necessary further actions from the public and private sector are included.*

Keywords: *autonomous vehicle, connected vehicle, transport planning, Sustainable Urban Mobility Plan, transport policy.*

1. INTRODUCTION

Serbia, together with other highly automobilized societies, is on the verge of a major technological disruption. Despite gradual innovation and total overhauls of components and vehicle technology, the concept of automobile has remained fundamentally stagnant over the last century. However, advances in sensing, communication, and computation technology have created conditions for emergence of self-driving vehicle (SDV) technology. The convergence of automation and connectedness will enable individual vehicles to navigate their environment by performing all safety-critical driving actions without the need for a driver. Moreover, these technical capabilities will, for example, enable the formation of cooperative vehicle systems [1] and generate significant amount of data. Similarly to vehicles in the 20th century [2], SDVs are predicted to be one of the biggest disruptive technologies of the 21st century, deeply affecting societies and economies worldwide, as well as a range of human activities, including traveling, working, socializing, etc. [3-5].

Several potential benefits are listed in support of SDV technology development, starting from reducing the number of road accidents and fatalities, fuel savings, congestion avoidance, and parking savings [6, 7]. Other predicted benefits include reducing vehicle ownership [7-9], ability to do other activities, such as reading or working, whilst travelling [10], or significant export potential [11]. However, there is are significant uncertainties and potential disadvantageous consequences leading to increased risk stemming from large-scale SDV deployment. Considering the unknown developmental trajectory of SDV technology, the foundational vision plays an important role. Thus, there is a requirement for a proactive approach, considering a range of localized features of the society and technology.

2. SELF-DRIVING VEHICLE TECHNOLOGY

According to their definition, SDVs can have different automation levels [12], starting from ”technology-augmented requiring driver assistance” to ”completely autonomous requiring no driver”. As it is often the case with disruptive technologies [13], SDVs have evolved from a confluence of different technologies. First component of technological convergence enabling SDVs was sensing technology that enabled real-time gathering of data about the vehicle and its environment (e.g., GPS coordinates, speeds, directions, accelerations, obstacles, etc.) [12, 14]. Second, development of short-range vehicle-to-vehicle and vehicle-to-infrastructure communication enabled transfer of periodic or activated messages that can inform the surrounding vehicles (or vehicle’s driver) and infrastructure, relaying data e.g., on vehicle’s speed, position, or direction [15, 16]. Third, computation technology enabled storing and processing of larger amounts of data, comparable to a typical personal computer [17].

Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
***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	Driver only	0
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	Assisted	1
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	Partially automated	2
***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	Highly automated	3
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	Fully automated	3/4
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**	-	

Figure 1. *Levels of Driving Automation for On-Road Vehicles*
Source: Society of Automation Engineers, German Federal Highway Research Institute BASt, US National Highway Traffic Safety Administration

In reality, SDVs are well under development in US, UK, Germany, France, Sweden, Netherland, Spain, Italy, Japan, South Korea, China, Singapore, and Australia [18]. In the US, Google has already rolled out prototype SDVs. The UK government is promoting the testing of SDVs in Milton Keynes, Buckinghamshire. Singapore is to start testing SDVs on its public highways in 2015. Mercedes-Benz is moving, incrementally, toward the development of SDVs: it already has demonstration vehicles capable of 99 per cent autonomous operation and commercially available vehicles that are 70 per cent autonomous. Volvo will have two test routes for SDVs in Göteborg by 2017. Cadillac division at General Motors is promising a "super cruise" technology in its 2017 models. Nissan is working on a range of SDVs that it claims will be for sale sometime between 2020 and 2025. Audi, BMW, Jaguar, Toyota, Continental, Bosch, Tesla, and Apple are some of the other companies that have publicly expressed their intention in developing SDVs. Moreover, Vienna Convention treaty was modified to allow the introduction of SDVs in Europe. On the other side, the State of Nevada has passed legislation to permit AVs on its highways. In addition to this, a range of information and communication technology (ICT) companies across the world have started developing organizational ecosystems for developing SDV and related technologies. For example, organizations such as Connected Vehicle Trade Association have already been formed, with the predictions that connected car market will generate a revenue of $141 Billion by 2020 [19].

Research and development related to passenger and freight SDVs has been carried out for several decades under different names (e.g., Automated Highway System [20]). Starting from 1990s, technological development has made significant progress on adaptive cruise control (ACC) systems that can maintain the distance to the preceding vehicle [21]. Recently, ACC has been supplemented by a range of other vehicle systems, such as, blind spot monitoring, obstacle and collision warning, lane keeping support, and emergency braking [22]. In the past several years, there has been a dozen of large scale projects related to developing and testing SDV technology (e.g., HAVEit [23], SARTRE [24], CityMobil2 [25], iTETRIS [26]). An example of one of the large-scale developments is establishment of an artificial urban environment for testing of SDV technology initiated by the University of Michigan Transportation Research Institute (UMTRI). Moreover, a recent US Department of Transport's Strategic Plan for Intelligent Transportation Systems announced realizing connected vehicle implementation and advancing automation as the primary technological drivers of current and future Intelligent Transport Systems (ITS) work across many sectors [27].

Smaller scale research projects have been focusing on specific aspects of SDV technology implementation. One of the largest groups of research projects focused on studying effects on traffic flow, concluding mostly positively changing flow properties as compared to traffic flow properties with manually driven vehicles [28-31]. In addition, there have been series of research project related to development of traffic control mechanisms (review in [32]), mostly concluding improvement to conventional traffic control (e.g., [33-38]). However, some research has attempted to point to the need for wider consideration when developing traffic management technology for SDVs [39, 40]. The second large group of research projects focused on in-vehicle human behavior in SDVs. This previous research stream suggests that high levels of vehicle automation result in reduced driver situation awareness as drivers show higher tendency to become involved with non-driving related tasks [41]. Moreover, previous research of human factors shows that there is an element of learning involved not only in knowing about system limitations, but also in responding to potential hazardous situations [42] (e.g., drivers might take approximately 15 seconds to resume control and up to 40 seconds to stabilize vehicle control [43]). Furthermore, there are some unpredictable behavior changes, such as tendency to avoid lane change, and consequent increase in travel time, for lower levels of automation [41]. Finally, previous research underlines changes in social interaction in between and in-vehicle that could potentially affect the quality of time spent in the vehicle [44].

Several surveys have been initiated to investigate public perceptions of SDV technology, showing contradictory results, and emphasizing the importance of relationship between human behavior and attitudes and introduction, adoption, and use of SDVs. In one of the surveys [45], two thirds of the participants a priori accepted fully automated driving and wanted to use it. Subjects stated intention to use fully automated driving on highways, in traffic congestion and for automatic parking, as well as expressed interest in driving under influence, despite the awareness of their responsibility. In a survey of British motorists [10], only 24% said they would consider purchasing the SDV in the future. In another survey, conducted by UMTRI in US, UK, Australia, China, India, and Japan [46], the majority of respondents had a positive initial opinion of the technology, and had high expectations about the benefits of the technology. The majority of respondents expressed a desire to have SDV technology. Contradiction continues in a recent survey of 2,000 drivers [47], 64% of participants said computers were not capable of the same quality of decision-making that human drivers exhibit, with 20% of drivers saying they would buy a fully autonomous car if one were available. In addition to these surveys, interviews with focus groups from California, Illinois, and New Jersey showed divided user opinions related to SDVs, with willingness to use SDV depending on the location the person is coming from and their gender [48].

Some of potential SDV benefits are mentioned in the previous section, including reduction in the number of road accidents and fatalities, fuel savings, congestion avoidance, and parking savings [6, 7]. Another often mentioned benefit is the potential for reducing individual car ownership, by enabling shared-vehicle mobility solutions or Mobility as a Service (MaaS) with mobility service operators providing a comprehensive and integrated range of mobility services to customers [7]. Previous research on vehicle ownership approximates up to 43% reduction in average ownership rate [8, 9]. In addition, one of the often mentioned benefits includes enhanced productivity for autonomous goods delivery vehicles [49] or changes in road design and maintenance [50]. Finally, previous research informs us that one of the potential benefits taken into consideration is a significant export potential [11] and potential for return on investment [51].

Besides a range of potential benefits, previous research also identifies several obstacles for large scale SDV deployment, continuing the argument of unsure benefits and disadvantages from SDV technology originating from the public opinion investigation [52]. The most often obstacles are infrastructure needs [7], data ownership, privacy, and cyber security [10, 46, 53]. One of the significant concerns present in general public bases on the opinion that hat electronics systems have become critical to the functioning of the modern automobile, and that these are presenting new human factors challenges [54]. In addition, respondents in previous surveys have expressed high level of concern whether SDV could perform as well as actual drivers [10, 46, 47]. In one of the large scale surveys, a majority of respondents (except in China and India) was also unwilling to pay extra for the technology [46]. Finally, there have been some research highlighting the potential for increase in total distance travelled, vehicle costs, liability issues, and losing jobs [6, 45].

Despite the recent positive trend in the development and evaluation of SDV technology, there is an evident and substantial lack of evaluation of larger socio-economic implications, neglecting the fact that technological change has economic, political, and cultural dimensions. In addition, methodologies implemented in previous research primarily stem from a reductionist perspective of SDV technology, failing to completely consider the subject of social practices, everyday behavioral routines and interactions that require the use of a vehicle for the enactment of sociality, such as household and work communities. For example, SDVs are consistently perceived as progressing only through discrete levels of automation, with isolated focus on SDV itself. Consequently, this completely neglects road network characteristics or human behavior in the vehicle.

It is important to emphasize that SDV and other related technologies are already under development. This foundational development is primarily happening outside of Serbia. This external technology development is adding another layer of disruptiveness, stressing the timely opportunity for Serbia to have a say in the future of its technological economy and shaping of societal structures. Otherwise, leaving the technological transition to global-market forces, will not only result in Serbia underutilizing this technology, but potentially having very detrimental consequences on the whole country

3. STATE-OF-THE-ART TRANSPORT PLANNING IN EUROPE

As described in the previous section, despite a number of international efforts related to SDVs, there is a lack of efforts in Serbia. Considering the context of SDV technological development, transport planners have to respond to the emerging technology and its potential disruption. As a benchmark for the state-of-the-art transport planning, one can account the concept of Sustainable Urban Mobility Plan (SUMP). SUMPs are a recently-created European-level policy tool; and the guidelines for their definition and implementation were published as recently as 2014. SUMP [55] is defined as “a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life.” Thus, SUMP “builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles” [56]. SUMP aims to represent a new approach to planning mobility that departs from the traditional transport planning, focusing on people instead of traffic. SUMP does so by aiming at the long term planning, and going beyond administrative boundaries to serve geographical areas. Among other SUMP elements, there is a greater focus on public involvement, better cooperation between providing agencies, as well as greater accountability and measurability [57]. Individual components of the SUMP process are depicted on the Figure 2. Considering the improvements to the SUMP framework so far, the current state of the SUMP process [58] includes:

- A focus on 'functioning cities' rather than municipal administrative regions.
- A focus on the future development of the urban area, transport and mobility infrastructure and services in the long-term as well as the short-term delivery plan for implementation.
- A careful assessment of the present and future performance of the urban transport system.
- A balanced development of all relevant transport modes; encourages a shift towards more sustainable modes; and puts forward an integrated set of technical, infrastructure, policy-based, and soft measures to improve performance and cost-effectiveness.
- A horizontal and vertical integration by means of a high level of cooperation, coordination and consultation between the different levels of government and relevant authorities; as well as appropriate structures and procedures.
- Transparency and participation.
- Monitoring, review, and reporting of the implementation.
- Mechanisms at Local Planning Authorities for ensuring the quality and validating the compliance of the SUMP with the requirements of the SUMP concept.

Figure 2. *Sustainable Urban Mobility Plan process*
Source: http://www.eltis.org/content/sump-process

However, although technological disruptiveness is usually determined in hindsight [59], simple thought exercises can allow one to realize enormous societal relevance and disruptiveness of SDVs in Serbia. Despite its advances in comparison to the conventional, four-step modelling based approach [60], the current transport planning paradigm does not have explicit mechanism for tackling significantly disruptive technologies, such as SDVs. As a result, there is a need for adaptation and evolution of planning principles, if benefits and disadvantages related to SDVs are to be managed locally.

4. BUILDING BLOCKS OF THE EXPANDED PLANNING FRAMEWORK

In order to respond to the disruption from the emerging SDV technology, there is a need for a novel methodological approach. With a deterministic approach to future, previous research neglects complex interdependence of system elements, and the inherent impossibility of linear prediction of consequences. This results in an approach where future is something already decided or “inevitable”, as opposed to the future being something that can be shaped. Considering the complexity of societal challenges and SDVs as sociotechnical systems, as well as the necessary solution-oriented approach, there is a need to combine necessary multidisciplinary perspectives into a novel methodological framework.

Such a methodological approach should build upon the state-of-the-art transport planning paradigm, such as SUMP. However, the novel planning paradigm needs to draw from the conventional technological transition theories. For example, the conventional multilevel perspective on technological transitions [61] recognizes landscape, regime, and niche levels of interaction. Socio-technical landscape represent macro level, long-term, relatively stable elements that provide context for transitions (e.g., trade conditions, culture, global political constellation, etc.). Regime include meso level, prevailing, mainstream order in activities among social groups. Finally, niche consists of origins of creation of novel technologies and practices in the micro level. Complementary theories have recognizes the influence of social networks around a specific technology, consisting of specific actors and institutions. Despite the fact that socio-technical landscapes have not been used for SDV technology, this perspective brings up an excellent point that social and technological changes evolve together, through mutual influence. Consequently, transitions are influenced by interactions between many social groups: public authorities, private companies, user groups, scientific communities, social movements, special interest groups, etc. However, this innovation-driven perspective fails to completely incorporate the modern life complexity, considerations for human behaviour, and mutual shaping between the social values and the technology.

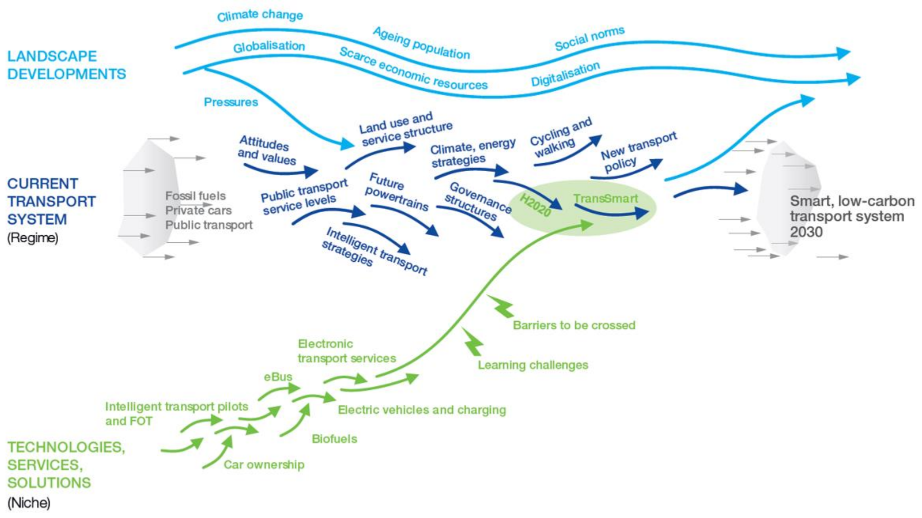

Figure 3. *Multi-level perspective on technological transitions in transport*
Source: Typology of sociotechnical transition pathways [62]

Besides the knowledge originating from technology transitions theory, an improved planning framework needs to build further upon the holistic understanding of the technology in a social context. Furthermore, the anthropocentric methodology should also be foresight-oriented. Thus, the intention of the framework is not to predict the future, but to help in building it by placing human as its central pillar. Consequently, the planning framework should include elements of action-orientation, openness to alternative futures, and participatory design, while embracing elements of complexity. On the contrary to the technology transition theory, the framework needs to progress away from the word 'landscape', which implies a complete picture of the present or future world and Archimedean standpoint. Instead, the planning framework replaces the idea of the 'landscape' with the term 'horizon'. In this context, the horizon implies a perspective that accepts a range of alternative futures, while simultaneously thinking about changes in tangible (e.g., institutional networks, company clusters, technologies, built environment) and intangible world (e.g., practices, societal norms and values). Similarly to the Energy Cultures framework [63] show on Figure 4, a comprehensive planning framework thus includes interdependency between societal norms, practices and material culture. Thus, the methodological approach observes SDVs as complex artefacts in a large sociotechnical system. This sociotechnical system includes people, hardware, software, physical surroundings, other technologies, institutional and business networks and procedures, laws and regulation, data and structures, etc.

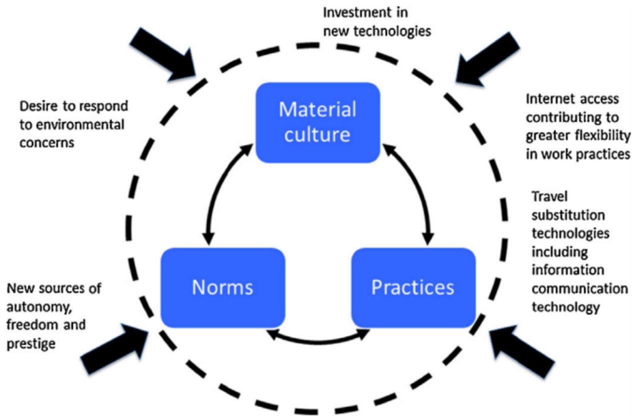

Figure 4. *Example of the Energy Cultures framework*
Source: Conceptualizing transport transitions: Energy Cultures as an organizing framework [63]

In addition to the expanded perspective, a novel planning framework requires a change in planning processes. Instead of the primarily expert-driven approach, there is a need for a participatory approach [64], which can create normative and desirable future visions and roadmaps [65]. Moreover, instead of forecasting, the planning framework should focus on a backcasting approach, by looking back from the desired future and creating decisive steps and pathways to the present [66, 67]. In addition, the recommendations for action should be planned as short-term (highly detailed), medium-term (semi-detailed), and long-term (general), with year 2040 as the temporal destination point for transition pathways. In this procedural approach, the planning framework can enable both bottom-up and top-down input. Finally, the planning framework should consider all automation levels, as well as different percentages of SDVs in traffic, different user profiles, and relations to freight transport.

5. POLICY RECOMMENDATION IN THE CONTEXT OF THE CITY OF BELGRADE AND SERBIA

Having in mind the previous framework components, this section will identify examples of the disruption in Serbia, with a particular focus on the City of Belgrade, as the largest metropolitan area. In addition, this section will present specific recommendation for future action from the public and private sector. First, following are some examples of SDV technology manifestation, with reflection of potential positive and negative implications, for Serbia and the City of Belgrade:

- SDV technology has the potential to address mobility needs of Belgrade region through cooperative vehicle platoons or new demand-based mobility services. However, in terms of in-vehicle comfort level, SDV might radically reconfigure the experience of traveling. While mobility is integral to the management of household or work communities, it is only one element in a support structure of the social organization and the human activities in locations such as households or workplaces. Consequently, despite being primarily a mobility technology, SDVs might relate to significant changes in human household, leisure, mobility, work, and other activity. These changes might result in an increased number of vehicles in use, increased urban sprawl, declined use of public transport, increased energy consumption, and detrimental environmental effects throughout the metropolitan area.
- SDV technology has a potential to improve traffic safety by removing human error. However, there are risks stemming from the existing infrastructural and technological legacies in transportation system [50]. For example, a failure to develop mechanism for proper infrastructure investment in combination with adverse weather conditions might result in detrimental technological and infrastructural failures, leading to negative effects on vulnerable road users, such as pedestrians or bicyclists, with lives and trust lost.
- SDV technology has the potential to provide highly needed mobility for elderly and disabled [68], as well as children. In the context is mobility of elderly and disabled, there is potential for improvement of functional and working ability. However, changes in human activity patterns from SDV use might also result in negative impacts on health and well-being. For example, instead of active living behavior, wide-spread adoption of SDVs might increase obesity throughout age groups. In addition, due to technological complexity or lack of trust [69] in SDVs, these vehicles might not be used by elderly, failing to prolong their working or functional capacity.
- SDV technology can enable economic development and productivity of the whole metropolitan region, providing efficient logistics services over long distances. Moreover, in the Serbian context, one aspect of changes might relate to increased flexibility in workplace location and emergence of new forms of employment [70]. One example includes changes in job descriptions, where delivery driver switches from being solely an operator of the vehicle, to include value-added services, such as household appliance installation. In the case of autonomous delivery vehicles, a person could still present, but instead of driving, the worker focuses on locating and collecting packages [49], or can perform other enriched tasks. In the case of social services, this could mean a home care worker that escorts the elderly from their home to meet other senior citizens. However, regional and economic equality may get worse if SDVs are too expensive for the lower income classes, or mobility

services cover only densely populated areas, thus creating mobility challenges for low income citizens in suburban areas.

These brief examples point to a range of potential changes, from travelling practices to societal norms, such as trust and equality. In addition to high emphasis on changes in human activity, SDV technology will affect a range of institutions and organizations. For example, SDV technology will affect taxi companies, ride-sharing companies, freight companies, retailers, air and rail companies, auto repair companies, hotels and rest areas, planning and engineering organizations, road maintenance authorities, mass transport agencies, parking agencies, real estate companies, telecommunication companies, consulting companies, enforcement, insurance companies, lawyer agencies, emergency health care providers, electricity suppliers, driving schools, vocational/trade schools and universities. All these, and many other institutions will need to reconsider their institutional structures, operational methods, and competencies in order to utilize SDV technology.

Consequently, there is an urgent need for a broad consideration of interdependent benefits and disadvantages stemming from SDVs in Serbia. Disruptiveness stemming from SDV technology will introduce significant changes and risks in the public sector, the private sector, and the civil society. The first step for action is the identification of institutional interdependencies and structures (e.g., legislation, administrative decisions, etc.), along with identifying institutional bottlenecks, is important for supporting comprehensive technology utilization. As previous research recommends [5-7, 71], public sector will need to have a very important role in influencing the complex technological transition process. Moreover, public sector will have an important role in enabling conditions to utilize SDV technology in Serbia, in a socially responsible manner. However, an approach would require an interdependent network of groups of stakeholders (actors), with a significant public participation in the process of transition (Figure 5). Despite the leading role of the public sector, a range of private and non-government stakeholders should be involved.

Considering the complexity of SDV technology, the groups of stakeholders will need to simultaneously focus on several aspects for developing optimal transition plans. One aspect is initiating a development of an integrated approach for land use, housing, transport, service structure and operating conditions for business. In general, the public sector will need to introduce coherence in policy portfolio, as opposed to current practice of 'silo-based' policies and local activities. In addition to vertical, horizontal, and timing coordination of policies, the public sector will need to consider a range of policies, from taxation to flexible regulation of work and incentives for working longer. Moreover, considering high technological dependence on road and communication infrastructure, the public sector will have to determine its role in relation to infrastructural investments [72] or ensuring mobility for all country's regions. This will potentially require the implementation of new operating models and methods for the public sector. For example, actions will require changes in funding schemes and municipal responsibilities. In addition, the public sector will need to recognize and cooperate with a range of agents of technological transitions, including corporations, researchers, non-government organizations, and citizens. Often, there are exceptional leaders and pioneers with cross-generational thinking that can skillfully connect and mobilize complex networks of actors across system levels and organizational boundaries. Serbian public sector can support societal actors and establish collaborative network by developing an understanding of those leaders and pioneers. Finally, in order to anticipate and manage risk, Serbian public sector will need to enable policy learning and develop strategic institutional agility, while improving conditions for institutional and decision-making transparency.

Adapting to change will also require that all societal elements have necessary skills, knowledge, and resources. It is important to remember that Serbia has the chance to develop supportive innovation networks and national-level value creation ecosystem of companies. Moreover, SDV technology has the potential to enable sustainable business activities based on renewable natural resources and integrated with social ways of providing services. For Serbian companies (particularly the SMEs) to play a significant role in the development of SDVs, the local ecosystem must be diversified by attracting new participants, such as large automotive companies, to join in and set up operations in Serbia. This would not necessarily mean manufacturing, but R&D, prototyping, and field-testing.

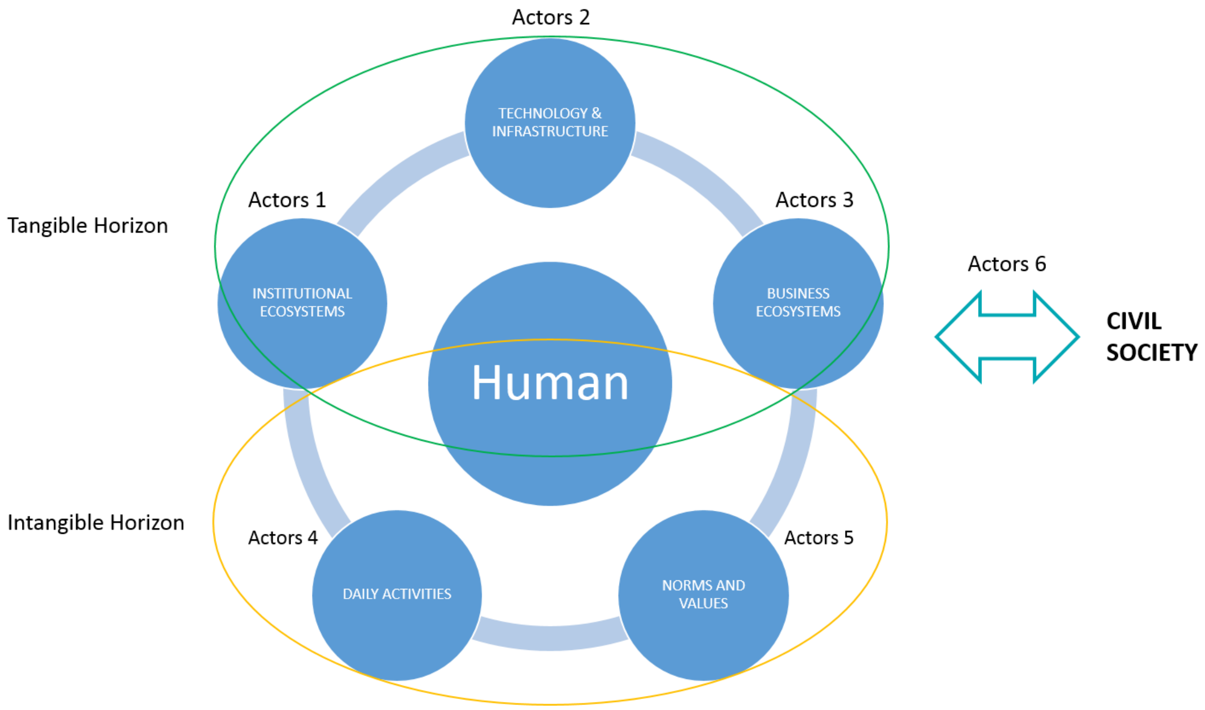

Figure 5. *Example of the proposed planning framework*
Source: Authors

As an immediate step required is setup of the legislative procedures for enabling SDVs in Serbia. Legislative support can support initial piloting and testing, necessary to contextualize further actions. One recommendation is that instead of generally allowing SDV operation in Serbia, a dedicated autonomous driving zones (ADZs) according to automation level (AL) are established. These ADZs might be implemented on certain road network sections, and potentially even at certain time periods. A simplistic example in Figure 6 shows allowing the use of SDVs of certain automation level (AL) at certain zones on the road network. Moreover, ADZs allowing lower level AL might be applicable to urban arterials. In a longer time span, the extent of ADZs and their AL will gradually increase. As further testing provides empirical evidence, ADZs might expand. This approach will also enable to account for a range of services and practices that will have to evolve along with the capability of automated driving, as well as a mixture of automation levels among the vehicle population, due to gradual renewal.

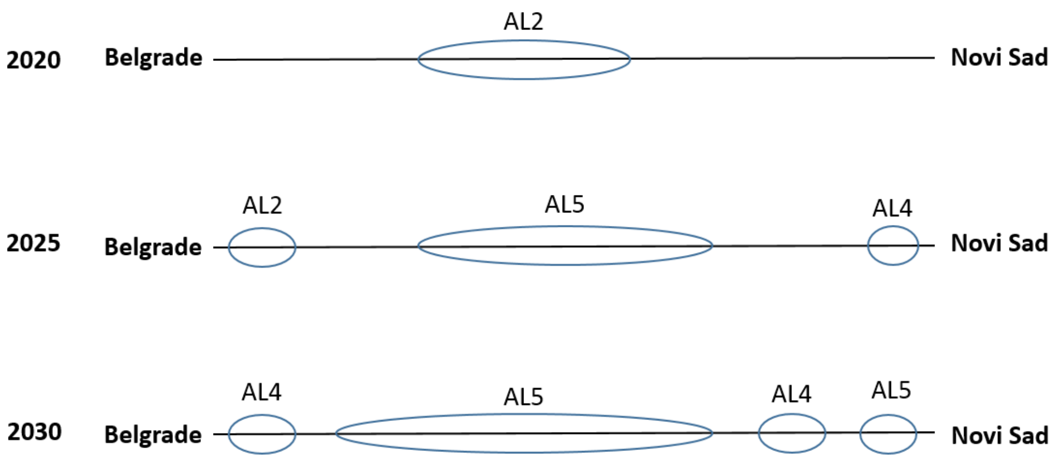

Figure 6. *Example of SDV technology roadmap for network segment in Serbia*
Source: Authors

6. CONCLUSION

Considering the advent of SDV technology and the level of potential disruption stemming from it, Serbia has to take a proactive role in technological transition, and shaping its future. However, taking into account the novelty of the situation that transport planning is facing with the advent of SDV technology, there is a need for a paradigm shift. Instead of focusing solely on transport and using forecasting methods, a planning framework needs to account for a range of elements, starting from travelling practices, societal norms, up to institutions and technologies. In addition, forecasting approach needs to be replaced with a foresight-based approach, imagining a range of alternative futures, and developing roadmaps to the present. This research presents such a new planning framework, building upon the SUMP approach, and combined with a perspective from technology transitions theories. This new planning paradigm will require development of a network of stakeholders, from both public, private, and civil society. An immediate step for improving the localized understanding of implications from SDV technology, legislation needs to allow the development of autonomous driving zones.

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