Smart mobility - Challenges for mobility policies and spatial planning

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Abstract

Smart mobility - Connected, Autonomous, Shared, Electric (CASE) mobility – it is shown to become a complex landscape of new transport technologies, infrastructures, services and systems based on Information and Communication Technology (ICT). Smart mobility will be generated, will serve and will be contained by smart urban systems, and this mechanism of mutual influences have to be well managed both through smart spatial planning and through specific smart mobility policies, in order to maintain the balance between accessibility and quality of urban life requirements. In the context of intense concerns regarding the evolution of smart mobility and its holistic effects, the paper proposes a synopsis of the potential social, economic, environmental, spatial impacts of emerging Intelligent Transport Systems (ITS), based on which two objectives are met: 1. drawing guidelines for smart mobility policies design, and 2. identifying the main categories of foreseeable spatial impacts of smart mobility.

The study builds on the conclusions of the author's documentation and research, individually and in national and international projects. There is a forward-looking approach, starting from a synthesis of current knowledge on smart mobility, based on information selected by the triangulation method. The paper concludes on the features of ITS-oriented mobility supply, on the related mobility behaviors, and on both positive potential impacts, which should be developed and encouraged by ITS policies and negative potential impacts, which should be strongly limited by these future policies. There are also identified the main categories of envisageables spatial - functional urban effects and transformations generated by ITS - at the level of the road network, street morphology, architectural-urban programs, urban structure - whose further analyze and understanding is mandatory for preparing cities to properly respond to the challenges and demands of smart mobility, while maintaining and even enhancing the quality of urban living.

Keywords: *Intelligent Transport Systems (ITS), mobility policies for its, smart city, connected autonomous shared electric vehicles (CASE-V).*

1. Introduction

The evolution of humanity faces a new paradigm shift – towards the "smart" human development - triggered by the disruptive evolution of science and technology, and particularly by that of the Information and Communication Technologies (ICT) - 5G technology, large databases (Big Data), Internet of Things (IoT). This new challenge occured in the context of the strong concerns for environmental protection, for curbing and limiting climate change by decarbonising the economy and the mobility.[16] Intelligent human development thus preserves the logic of sustainability, further capitalizing on the performances and efficientization announced by the digitization and robotization of activities. This new, global „*smart development*" paradigm triggers changes of all the planning models specific to various fields, leading, for example, to "smart mobility" and "smart city" new planning approaches.

A *smart city* will be an urban territory (urban area) that will integrate complex information and communication technology (ICT) able to collect and manage large amounts of data, to connect many systems and to ground real-time responses so as to enhance the lives of citizens. "IoT sensors, video cameras, social media, and other inputs act as a nervous system, providing the city operator and citizens with constant feedback so they can make informed decisions." [8]

Smart mobility is about to become an ICT-based, multimodal, sustainable, optimized urban mobility system within the smart city, interconnecting many different types of ITS through smart management. New, specific, mobility policies are to be developed. [11],[17], [25],[37]

In the context of intense concerns regarding the evolution of smart mobility, this paper identifies *a synopsis of the positive and negative potential impacts of emerging Intelligent Transport Systems* (ITS): *spatial, social, economic, environmental,*. Based on it, some general principles for designing *ITS-oriented mobility policies* further adress bowth the *positif potential to be harnessed through „pull", incitative measures* and *the negative potential whose manifestation should be mitigated through „push", dissuasive measures*. The main categories of foreseeable spatial impacts of smart mobility are also identified.

2. The research method

The study builds on the conclusions of the author's documentation and research works, individually and in national and international projects, and particularly on that related to WISE-ACT, COST project. There is a *forward-looking and thinking approach*, relying on the current knowledge on smart mobility. This general state of the art framework was achieved, using the triangulation method, through the analyze of three categories of information: theoretical and research studies - *reports and predictive studies on smart techology advancements* [2],[3],[6],[10],[15],[22],[24],[26],[27],[28],[29],[35],[36], [39], [40],[47], *surveys* on relevant public perception [1],[12],[13],[21],[23],[44],[48] and *multidisciplinary discussions on technical and planning issues* (with transport and environment engineers, urban planners, sociologists).

3. Intelligent transport systems - potential features and impacts

After several decades of quasi-linear evolution, in the recent years, the transports experience a disruptive evolution triggered by the accelerated development of ICT: *new transport technologies that integrate ICT* - autonomous and connected vehicles (drones, autonomous cars, flying cars with / without driver), intermodality and interoperability - *new types of ICT based mobility services* (on-demand transport, sharing schemes - car-sharing, bike-sharing, scooter sharing, ride-sharing, integrated transport services - MaaS, etc.), and even *challenging, new, spectacular transport systems* (such as Urban Air Mobility, hyperloop). [10],[14],[15],[18],[41],[50].

These evolutions come with a huge but yet partially unpredictable potential to change the mobility landscape in terms of *urban mobility supply* (infrastructure, fleets, services), *travel behavior* (modal options, travel characteristics) and also in terms of *urban, environmental, social, economic, impacts, both positive and negative*. In the frame of the current knowledge, through a looking-forward approach, it was identified *a synoptic table of the foreseeable potential impacts generated by the new characteristics of Intelligent Transport Systems - autonomy, connectivity, sharing and electrification*. (Table 1), [4],[5],[37], [42], [45],[46],[50]

Table 1. The sinoptic of the potential impacts of the Intelligent Transport Systems

SMART MOBILITY-ITS features	**MOBILITY BEHAVIOUR** Potential trends positive ☐ negative ☐	**Potential impact(s) on** positive ☐ negative ☐		
		Mobility	**Urban space**	**Social, economic, environment**
SHARED (car-sharing, bike sharing, scooter sharing, ride-sharing)	**Mobility behaviour less based on personal car use and reorientation towards shared-vehicles** *(requires social acceptability)*	▪ **Lowered motorization rate** (no. motor vehicles / 1000 inhabitants)	▪ **Less urban space and less built surface consumed by parking**	▪ **Lower costs of personal car use** (elimination of costs related to their ownership) ▪ **Limitation of social exclusion / discrimination related to transport**
Diversified shared fleets (with different types of vehicles); Customized transport	**Differentiated choice and use of vehicles**, depending on the travel purpose and needs, on the passenger's number, etc.	▪ **Optimized, efficient transport**	▪ **Less road space consumed by traffic and its improved (re)allocation**	▪ **Lower / optimized costs of individual travels** ▪ **Lower negative environmental impact**

AUTONOMY (& robotization) – Self-driving cars - level 5 (SAE International, [43])	**More car users (children, the elderly, people without a driver's license, blind people, etc.) -** *Increased demand for car use* **Higher travel time budget** (as a result of using travel time for other activities as well)	▪ **Higher volumes of individual motorized travel** ▪ **Increased commuting in terms of distance and traffic volume** (due to the use of travel time for other activities) ▪ **Increased traffic congestion**	▪ **Higher urban space consumed by traffic** ▪ **Low quality of public space** *or* ▪ **Efficient use of road space** (through automatic driving and parking)	▪ **Economic benefits** - travel time saving - (many) use of travel time for other activities ▪ **Environmental benefits** through automatic eco-driving (including energy saving functions) ▪ **Limiting social exclusion related to transport** ▪ **Decrease of accidents & fatalities**
Transport on demand - Possibility to "call a car" in any location, at any time (with smart devices)	**Mobility behaviour less oriented on personal car use**	▪ **Lower motorization rate of the population** ▪ **Flexibility and customization of transport services** ▪ **Reduced "last mile" related issues**	▪ **Improved accessibility to transport within low-density peripheral and periurban areas**	▪ **Increased users' satisfaction with public transport systems**
CONNECTI-VITY	**New social culture and practices related to IoT**	▪ **Connection and transfer of information, in real time**, with other vehicles and other elements of the environment, **interoperability** ▪ **Optimized traffic management –** lower traffic congestion	**Traffic management adapted to the situations of the urban areas - pollution, congestion, etc**. (multimodal variants – MaaS, bypass routes, etc.)	**Benefits deriving from the optimization of transport systems** (social and economic, related to time saving, environmental benefits related to reducing pollution, etc.)
		▪ **security issues - multiple vulnerabilities**		

ELECTRIC TECHNO-LOGY	**Gradual replacement of the private vehicles on fossil fuel with electric vehicles** **(**supported by incentives and deterrents)	**Decarbonization of mobility**	**Integration in the territory and in the public space of the infrastructure for ICT and for charging electric vehicles**	**Low economic and environmenta l costs** (if green energy is used)

Source: *Synthesis made by the author*

Concluding, the new features of Intelligent Transport Systems bring a significant potential for positive impacts:

- *on mobility behavior(s)* (less oriented on personal car use, more oriented on shared-mobility, public transport, lower car ownership),
- *on urban mobility* (optimized and efficientized transport, through improved traffic management and interoperability, travel time savings, flexible and customized transport, modal split restructured in favor of a more convenient and attractive public transport, including sharing systems, fewer and lower traffic jams, reduced "last mile related issues – new door to door accessibility , lower motorization rate, new forms of accessibility – „urban aerial accessibility”)
- *on urban space* (efficientized use of public space – its lower consumption by moving or stationary cars, improved ambience through contextualized mobility schemes, improved accessibility to transport within low-density peripheral and peri-urban built areas), [19], [20], [49]
- *economic* (travel time savings, multi-use of travel time, reduced costs of private use of cars by increasing their utilisation rate within shared fleets)
- *social* (mitigation of social exclusion related to accessibility and mobility, through transport on demand and autonomous vehicles, decrease of accidents and fatalities rate, increase of users' satisfaction with public and shared transport)
- *environmental* (reduced pollution, curbed and limited climate change – decarbonizing urban mobility [16])

At the same time, as shown in Table 1, ITS new features might also generate negative impacts, especially related to the use of autonomous, self-driving vehicles (level 5 robo-cars). That new type of driverless technology would be additionally used by categories of people who previously did not have the opportunity to use a car independently (children, elderly, people without a driver's license, blind people, etc.). That could lead to an increase of the individual motorized travels and thus of the traffic volume, with higher space consumption and pollution.

Also, the possibility to use the travel time for other activities as well could lead to the increase of daily travel time budget, of daily commuting journeys length, and thus of the traffic volume. It could also lead to an effect of increased urban sprawl, in a larger and less dense periurban area, with lower potential to be well served by public transport.

Important concerns are also related to the vulnerabilities of computerized transport systems, such as cyberattacks.

Harnessing the positive potential while limiting as much as possible the expressing of the negative potential can be achieved only through intelligent policies for smart mobility.

4. Policies for smart mobility - Benchmarks

4.1. From city to metropolis. From plans to policies for urban mobility

In the last decades (since ’60 in western countries, since ’90 in eastern, former communist countries), there has been a spectacular evolution of urban settlements, characterized by demographic and territorial growth. „Today, 55% of the world’s population lives in urban areas, a proportion that is expected to increase to 68% by 2050. Projections show that urbanization, the gradual shift in residence of the human population from rural to urban areas, combined with the overall growth of the world’s population could add another 2.5 billion people to urban areas by 2050(…). By 2030, the world is projected to have 43 mega-cities with more than 10 million inhabitants, most of them in developing regions.” [29]

Urban territories have transgressed administrative boundaries of main *cities* and have evolved from single Territorial Administrative Units to urban systems that we now call "*Functional Urban Areas*" (FUAs) or *metropolitan areas*. FUA is a larger area of daily life, calibrated by the daily commuting flows between a main city and its surrounding localities that it influences and polarizes. This phenomenon of urban expansion has been triggered by the spectacular evolution of transport systems (especially by the exponential increase of automobility and by the rise of vehicles speed performance). [32]

Metropolitan travel systems achieved a complexity that could no longer be managed through the caduques principles, models, methods and tools of the classic "traffic planning". This approach became obviously inadequate, seen the high magnitude and unsustainable trends of the motorized traffic negative impacts. Since the ‘70s, with the adoption of sustainable development logic, mobility approach and planning also stepped towards a new paradigm, that of *sustainable mobility*. This involved complex changes of principles, methods, tools, models. (Fig. 1), [32]

A general, major change has been the shift from travel systems planning through *short-term sectoral approache*s, such as "traffic plan", "transport plan", "traffic study", to *integrated, multidisciplinary planning*, based on a *long-term vision*, which before setting action plans builds *sectoral mobility strategies and policies aimed at creating a multimodal mobility offer, for the (re)model of mobility behaviors in the logic of sustainability.* This logic is mainly translated into two major specific objectives: 1. *reducing the ecological footprint of mobility* and 2. its “urbanization”, in the sense of its more *harmonious, contextualized insertion, in urban territories, tissues and spaces.* (Fig.1), [32]

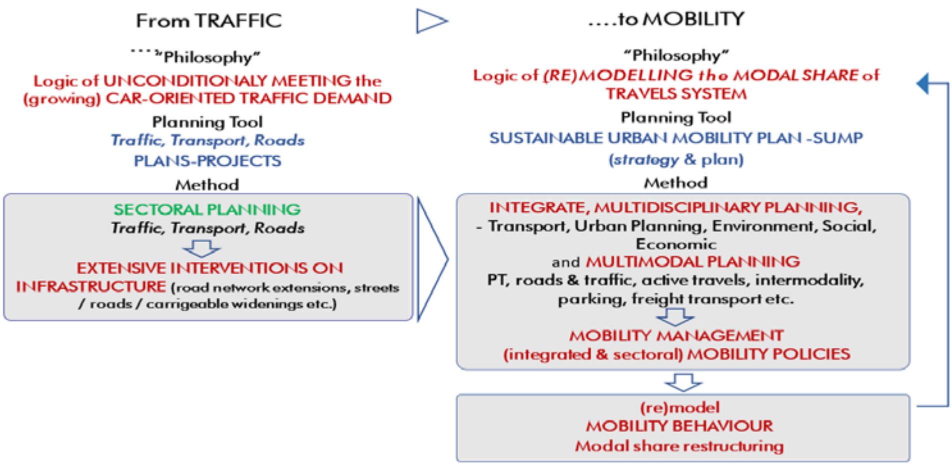

Fig. 1. Mobility paradigm change – "from Traffic to Mobility"
Source: Negulescu Mihaela, Mobility Plans and Policies- master course, UAUIM

Also, mobility policies are no longer focused only on creating *"hard" offer* - infrastructure, fleets and transport services (which require significant investments) - but also identify ***"soft" measures*** – pricing and taxation, regulations, information campaigns etc. (which do not involve high costs). Both categories of measures are thought in a systemic way, coherently and convergently, in order to obtain *incentive effects* and *dissuasive effects*, through which the mobility behavior of the population can be influenced and channeled towards achieving the previously mentioned specific objectives. [32]

4.2. Smart Mobility policies

As previously shown, ITS come with new features and new challenges, with a huge positive potential, but also with a potential for negative impacts (point 3). Appropriate specific planning and implementation frameworks (institutional, legislative, regulatory, financing) have to be developed for smart mobility policies - for Connected Automated Shared Electric (CASE) mobility. The new, smart transport technologies, systems and services have to be integrated so that their positive potential is effectively exploited, through incentives / pull mesures, and the evolution towards potentially negative effects, through dissuasive / push measures, is discouraged. (Fig.2), [38]

Based on the synoptic table 1, we can conclude that smart mobility policies have to build new mobility schemes and coherent packages of hard and soft measures (related to infrastructure, fleets, services, regulations, financing and business models etc.) aimed mainly at:

- Encouraging mobility behaviors based on the individual or in common use of shared vehicle fleets (public transport, car-sharing, bike-sharing, scooter-sharing, car-rental, ride-sharing), which would lead to a reduced motorization rate and a lower urban space consumption by parking. For the individual use of shared vehicles, micro-mobility systems with small vehicles are especially encouraged.

- Encouraging transport on demand schemes, which would reduce dependence on one's owned car and could improve the accessibility of the low-density areas, poorly served by traditional, planned forms of public transport.
- Discouraging individual mobility with autonomous vehicles, for long-distance journeys, which could increase traffic volumes, traffic jams, and exacerbate the consumption of urban space by moving and stationary vehicles.

Smart mobility policies, acting as mobility behavior modelers, should also be designed taking into account the levels of acceptability, the perceptions and social expectations, the attitude of transport users' towards CASE schemes, that are identified through public consultations and surveys. [34]

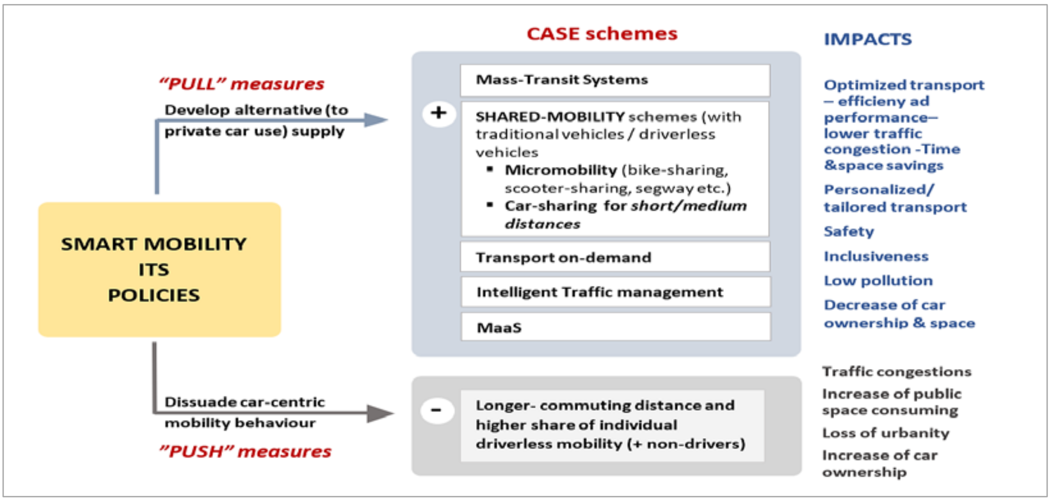

Fig. 2. Push&pull general approach of Smart Mobility policies – CASE schemes and impacts
Source: *the author*

5. Smart mobility in smart cities

Urban planning and design, in the broader logic of the "*smart city*", will also have to relate and to adapt to the new features of ITS, to deal with *new forms of accessibility*, with *new spatial requirements and potential impacts*, that are too little studied and understood yet. The *accelerated evolution of transport technologies* is in high contrast to the *inertia of urban settlements* which thus do not achieve adequate Automation-readiness', that can be defined as „the capability of making structured and informed decisions about the comprehensive deployment of CAVs in a mixed road environment". [7]. This could lead to an "urban shock" *when smart mobility systems will emerge within urban environments that are not ready to properly contain* *them*, when the regulatory framework is not sufficiently prepared to manage the new technological reality. This might be comparable to the shock of the explosive grew of automobility, since '50s, that generated huge negative impacts, due to its poor management. Therefore, without delay, there is a need for prospective studies on *models of intelligent, non-conflicting, contextualized insertion of ITS in urban territories and spaces*. [9],[30],[42],[45],

Based on current knowledge and anticipative studies on the characteristics of emerging technologies (connected autonomous vehicles – aerial and terrestrial), several major directions for adapting cities to new transport models can be anticipated, in a forward-looking approach:

- *Integration of ICT intelligent infrastructure* (sensors, meters, 5G antennas, etc.) *in the urban territory and space* (regulations, locations, aesthetics) [39]
- *Remodeling of the road infrastructure*, taking into account both new functional requirements of the ITS, and urban exigencies [2],[3],[30], [33],[37],[42]:
- Reorganization of the *road networks* (hierarchy, connectivity, differentiation, specialization etc.)
- Reorganization of *streets morphology* (allocation and configuration of space) and *rules of their use* (regulations related to speed, priority of passage, conditioned access, use of curb space etc.)
- *Smart streets – streets that integrate the smart environment hypostasis*, (fig. 3)
- *New intelligent parking systems*, without driver, on street or off street, for classic vehicles and/or for self-driving and self-parking cars (more efficient in terms of space and time consumption, due to automated parking and reduced maneuvering space), with new architectural models an attention payed to their integration into the urban space and landscape.) (fig.4)
- *Integration of new intelligent mobility schemes* (shared fleets, driverless transport schemes) in urban territories - location, sizing, functionalities, design(s)
- *New urban and architectural programs related to ITS* (multifunctional hubs of shared fleets with shared use - shared mobility, heliports for drones, etc.)
- New regulatory framework and *(yet unregulated) models of urban aerial space use by the Urban Air Mobility ("vertical" mobility)*

At a structural level, urban territories will probably face challenges related to the tendencies of extension of daily life-territories (urban areas), due to the use of travel time budget also for other activities and also due to a larger digitalisation of jobs and public services.

The need for a better quality of urban living conditions the future ITS design, in terms of decreasing pollution and space consumption exigencies. Electrification of transport technology it is expected to meet the target of mobility decarbonization. For *limiting the consumption of urban space* by moving or stationary vehicles there is need for a large focus on *shared-mobility schemes*, *intelligent parking models* and on the *use of small vehicles for individual transport* (cars – fig. 4, bicycles, scooters, segways, etc.). [19] A good example for the kind of small vehicles to be used in dense urban environments is the electric two-seat pod, with "robot wheels" named "city-car", designed at the Massachusetts Institute of Technology by the Smart Cities Research Group, lead by William J Mitchell. Hiriko Driving Mobility consortium built on that concept the prototype Hiriko Fold, a folding two-seat urban electric car. (fig.4).

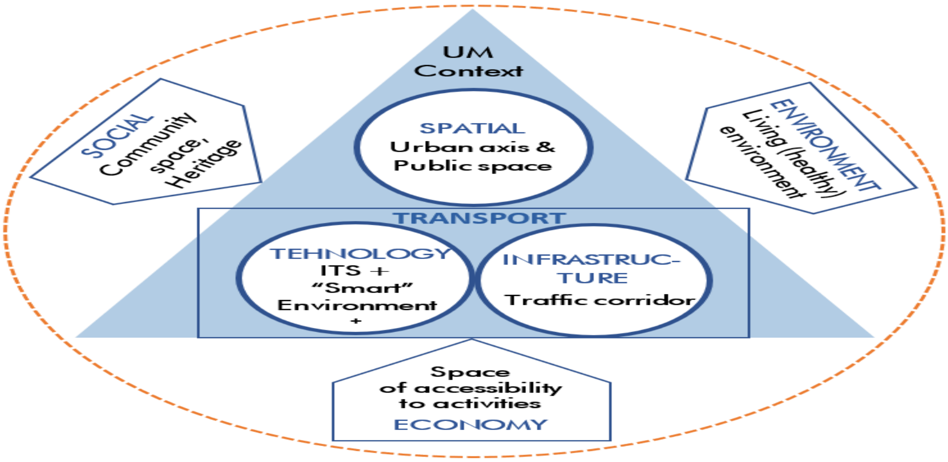

Fig. 3. Holistic planning of streets, integrating three hypostases: 1. Urban axis, community space and urban landscape, 2. Traffic infrastructure, 3. Smart environment for ITS
Source: *Negulescu, Mihaela, 2019, Smart Street reDesign- The first multidisciplinary student workshop in the field of urban mobility, in Romania - Research through project, IGLOO no 190/iun-iul 2019*

Fig. 4. Small vehicles: a) MIT's Stackable City Car, *Source: https://inhabitat.com/transportation-tuesday-mits-stackable-city-car/, b)* Stackable cars - Light weight L category electric vehicle that can be stacked together to gain space – to be developed in the Easily Distributed Personal Rapid Transit (ESPRIT) project, ***Source:*** *ESPRIT project http://www.esprit-transport-system.eu/*

6. Conclusions

For the deployment of new intelligent transport systems (vehicles, services, infrastructure) in the smart cities of the near future, beyond a whole specific ecosystem (legislative, regulatory, institutional, financing and business-models) that is to be organized, *smart mobility policies should be developed, so as to meet, in a balance manner, both accessibility and quality of urban living exigencies*.

The Smart city, as the physical container of the new forms of smart mobility, will also have to adapt to new spatial and functional requirements and change certain of its structural, morphological, configurative features. All these challenges require prospective, forward-looking approaches to achieve adequate "automation-readiness" and to avoid disfunctional eruption of the ITS in a not properly planned and managed context.

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