Developing smart city transport applications: *lessons and suggestions based on the EU experience*

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Abstract

This paper goes through the various aspects of smart-city transport developments that will be likely to be implemented in the near future. It presents the context of future smart city transport applications in terms of the technologies to be used, the user requirements and their expected behavioural changes, the data collection and monitoring, and the need for integration across all levels. It then gives three examples of smart city transport developments. They refer to the first case of a successful smart-city development in Greece (the city of Trikala) and to two large EU funded research projects that are dealing with the development of smart city transport applications (project *Citimobil2*) and autonomous mobility (project *Show*). The overall message is that smart city transport technological breakthroughs and innovations should go hand in hand with sustainability and livability objectives and should be mostly led by user requirements (i.e. bottom up).

Keywords

Smart-city, Transport, ITS, C-ITS, Information Technologies. Autonomous transport.

1. Introduction

According to the European Commission, a "Smart city" is defined as the urban area where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and businesses[2]. This simple and straightforward definition hides a multitude of Information Technology (IT) applications in all aspects of city life that aim at improving the management and efficiency of the urban environment. As Transport is one of the most used networks in an urban area that connects people and businesses and carries goods around, its efficient and IT assisted operation forms a vital part of the concept of a "smart city". Intelligent Transport Systems (ITS), are IT applications providing some degree of intelligence in the vehicle or at the roadside with a view to facilitating a more efficient and safe transport network operation. There are many IT technologies and applications that have been and are being developed many of which incorporating Artificial Intelligence (AI) and other features [1], [2], [3]. When we have a number of ITS applications linked and cooperating together –via telecommunication and data transfer technologies such as 5G networks, we have the *Cooperative ITS* or C-ITS. Through C-ITS, vehicles can connect and interact with each other (V2V), the road infrastructure (V2I) and other road users (V2X).

A major advance in smart-city operation will be the introduction and full use of the physical internet or Internet of Things (IoT). Already many Smart city transport applications which rely on "bundling" together a number of C-ITS applications, are relying on the IoT to be connected together and form specific, transport related, services [4], [5], [6], [7]. The idea is to

Models and Methods for Researching Information Systems in Transport 2020, Dec. 11–12, 2020, St Petersburg, Russia
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[2] European Commission, at: https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

provide advanced passenger and freight mobility with equal opportunities for door- to-door journeys if possible by making use of combinations of modes. A good review of the many technologies and especially AI and IoT applications for smart cities (all sectors not only transport) can be found in [8].

In the search to develop and have fully functional "smart-cities", the European Commission has supported the development of guidelines for smart city applications. The most recent of such guidelines is the *Smart City Guidance Package* that explains how to develop and apply an integrated approach in planning and implementation of smart city projects [9]. It explains the different stages in developing a coherent roadmap and gives examples and key success factors (and also common pitfalls) for the introduction of smart city applications.

An almost ubiquitous weakness in all the smart city literature is the extensive focus on technology and its applications with little or no regard to the user needs and to the need for "integration" of all the C-ITS bundles. In other words we need to pay more attention to how we can move from a "vehicle-focused" to a "system-focused" perspective based on user needs. To give an example, all modes of transport should be included and integrated in a smart city transport environment especially the more environmentally friendly ones such as cycles and cycling [10].

A second weakness is the fact that ITS and C-ITS applications are mostly considered in isolation, i.e. as "stand-alone" systems with little consideration of their economic, social and ecological environment. However, if they are to form a vital and "active" part of a smart city environment they need to be considered, and accordingly planned, as part of the wider smart city applications, technologies and business environment [11]. A systemic approach, covering all other relevant smart city services and sectors is therefore necessary when planning the transport applications so that they are integrated both among themselves and with the rest of the smart city sectors. A further weakness is the apparent second priority given to the "green" dimension as opposed to the "technology" dimension. This means that at equal level with the solving of the technical problems associated with the development and installation of the various smart city (transport) technologies, we should have the maintenance, the atmospheric emissions and other environmental impacts of these technologies, even the recycling of redundant materials and so on.

This present paper deals with these and other issues concerning the Transport C-ITS applications in smart cities. It reflects the author's experience from relevant applications in Greece and Europe and refers to the challenges that are faced for more integrated, green and user-oriented smart city transport applications.

2. The context of smart city transport applications

2.1. The technologies

The main carrier of smart city transport applications are the various intelligent transport technologies that have been or are being developed in the last decades. These, are combined and impacted upon by "external" (to the transport system) technologies which are also now being developed and gradually deployed. Figure 1, shows this interaction in a diagrammatic way. The main transport technologies that are available today, include all the vehicle related ones (e.g. for cleaner engines, driverless - autonomous and connected vehicles, and so on. Same for infrastructures and software (see Figure 1).

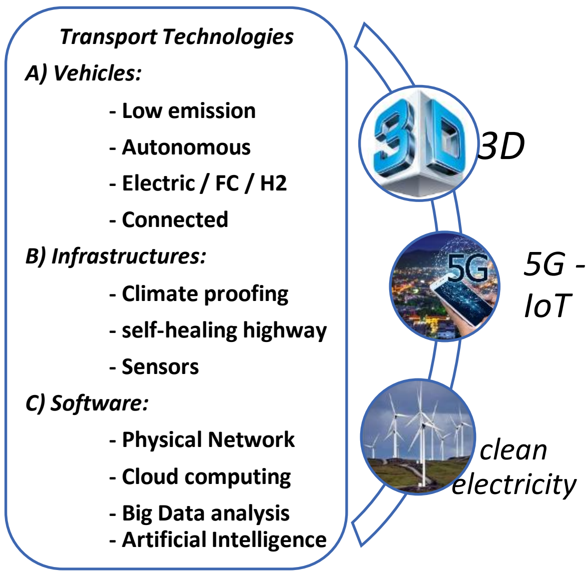

Figure 1: Smart city transport technologies and external influencing ones (indicative)

To these technologies there a number of external innovatory developments that will certainly influence and shape the smart city transport landscape of the future (e.g. 3D printing. 5G cellular communications, IoT, as well as clean electricity production technologies). The technological developments occurring or anticipated for smart city transport applications have the potential to be transformational – i.e. revolutionize the way we travel. For example, cloud computing, the dual-carbon battery, the electrification of highways, 3D printing and cloud computing may prove fully "disruptive" technologies. At the same time inter-connectivity between transport providers and between providers and users, needs to be raised to a much higher level and several smart city ITS applications are aimed at raising this level.

2.2. Smart city traveler behavioural changes

The full deployment of smart city technologies will need to be followed by thorough changes in the travel behaviour of the citizens involved. New and extensive paradigm shifts, the adoption and familiarization with new and disruptive transport technologies and changes in their related business, social or physical environment will demand radical (I should say) changes in our daily travel behaviour. We will be entering such a period of transformation that it would not be unrealistic to suggest that some form of action may be need to train or "educate" the travelers in the new environment, especially as regards the need for them to use and respond to smart city developments such as:

- Discontinuities in long term trends in key trip-making characteristics such as, for example, off-peak mobility i.e. traveling off-peak hours, abolition of car ownership and use of ride-sharing services or mobility as a service (MaaS)[3]. Also, similar changes to the way goods are delivered and distributed around[4].
- New risk profiles regarding road safety due to autonomous driving or new risk factors due to extreme weather, cyber threats, energy crises etc. Recently, there has been a dramatic increase in the frequency, intensity and duration of extreme weather events due to climate change.
- New transport capacity offers due to greater willingness to collaborate all around in the smart city transport businesses which will be fundamentally changing the pattern of demand for passenger and freight services.
- New, smart city related, policy perspectives and objectives (e.g. on decarbonisation in the transport sector).
- New life-styles. As an overall result of smart city developments our lives will gradually change and new life-styles will develop with more complex interactions of demographic, sociological, employment and communication nature. The new life-style that appears already (greatly expedited by the COVID pandemic) is that more people will be falling into the LAT category ('living apart together') and this will redefine the concept of "locality" in urban areas. E-commerce is also rapidly and drastically changing the mobility patterns and last mile logistics in our urban areas. So, overall we must make sure that smart city urban duelers retain their healthy lifestyles while reshaping transport demand. Life styles and associated travel behaviour will of course also be affected by the financial situation in Europe and elsewhere.

2.3. Data collection and monitoring

Relevant to the smart city transport technologies it must be stressed that a common European-wide system for smart city transport data collection and monitoring should be implemented that will have:

- Low cost monitoring devices;
- Low communication costs ;

[3] Vehicle sharing includes car/bicycle sharing as well as carpooling (sharing rides). Global membership of car sharing services is rising, with 12 million people expected to be part of a car sharing system by 2020 on a global level. Car sharing not only responds to a demand for more flexibility, it also promotes a wider use of multimodal transportation and helps to ease traffic congestion. It is estimated that for every car entering the car sharing pool, four to ten cars are removed from the streets. The resulting environmental improvement would be even greater if electric car sharing were adopted.

[4] We are already experiencing such changes (to delivery services) recently due to the increase in e-commerce as a result of the COVID-19 pandemic.

- Uniform storage of data in appropriate data bases set up on a country (or regional) level;
- User interfaces standardized so as to provide pan-European easy access to the system;
- Host of applications open to private or PPPs operators covering all possible aspects of needs such as: traffic management, user information, toll collection, road assistance, variable circulation fee collection, environmental taxation and restrictions, navigation, and many more.

A common feature of any smart city transport data collection system, will be the ability to manage and analyze large quantities of data (terabytes per day). "Big data" techniques and relevant computing infrastructures are therefore a necessary feature of any future smart city transport system with the aim to provide useful real-time information to all users of the system [12].

2.4. The need for integration

"Bundling" of C-ITS applications to produce specific services, is a first level of integration that is necessary within a smart city transport system. The integration of all bumbled C-ITS into a single city-wide system monitored and controlled by a control center, is the second level integration that is necessary. There is also a third level integration that is necessary and this is between the transport-related applications and the other smart city sectors related applications (e.g. in areas such as health, education, services, etc.).

In all cases of integration the following "integration principles" are recommended:

a. Strive for open, modular and extendable systems;
b. Bring together all sub-systems and services under one common user friendly environment;
c. Try to integrate also at a cross cutting level e.g. among transport modes, between passenger and freight transport, urban and inter-urban transport and between transport and the land-use system.

3. Smart city transport challenges

Smart city transport applications are faced with a number of challenges. At the highest level they must be consistent with the overall governmental policies for achieving a sustainable, safe, efficient and inclusive society. At a sectoral level, i.e. the transport and the other relevant smart city sectors level, there are a number of challenges which can be identified as follows:

a. How to use transport as an enabler of urban renewal;
b. How to contribute to achieving the required level of climate change, air pollution reduction and noise mitigation in the transport sector;
c. How to manage the impact of demographic trends and, in particular, the ageing population;
d. How to harness effectively the capabilities offered by IT and artificial intelligence;
e. Measure and manage uncertainty and risk at all levels;
f. Produce infrastructures that are resilient to extreme events (weather, etc.) as well as be well maintained ;
g. Maximize safety and security in the system (preventing loss of life and adverse health effects);
h. Take extra care in incorporating autonomous (driverless) transport vehicles into the rest of the traffic flows in the intermediate period of joint operation;
i. Harmonize all the above with the need to reduce and eventually eliminate the dependence on fossil fuels.

4. Some European examples

Smart city related C-ITS developments are being implemented all over Europe. They are mostly stand-alone systems that are put up for demonstration and assessment but some of them become permanent.

One very interesting real-life implementation of an integrated smart city system, with which this author is familiar, is the ***smart-city Trikala*** in Greece. This is a medium sized city of approximately 80 000 population in the middle of Greece in a predominately agricultural area whose municipal authorities over several years, starting in 2004, started applying ITS and other sector smart services as part of an integrated concept for the development of the Trikala as a smart city (initially called "digital" city). The first set of applications, was financed in 2004 by Greece's Ministry of Economics. Three years later, Trikala had established a fiber network linking 40 buildings and formed, with eight neighboring communities, a cooperative named *e-Trikala* to operate it and introduce a broadband culture of use. By 2008, *e-Trikala* had installed twelve broadband wi-fi nodes and quickly gained 10 000 users[5]. Access was free to residents and visitors after they register at one of the many *e-Trikala* offices. To build usage, e-Trikala has launched online services including public policy forums, tele-health and a specially designed web portal connecting customers to Trikala businesses. The wireless network also controls information displays for the bus network, improving service and increasing ridership. More recently, e-Trikala expanded the wireless network and begun deployment of Fiber to the home (FTTH) lines for businesses and households. Other notable developments in the city that lead it to become Greece's first smart-city, included:

- ✓ Installation of an integrated e-city control center which monitors everything from parking spaces to the town hall's monthly budget;
- ✓ The *e-Trikala* supplied all of the city's 120 public schools *Lego* and *Raspberry Pi* robotics kits;
- ✓ Trikala was the first city in Greece to try the 5G technology;
- ✓ Through the participation in many EU funded research projects, the city has managed to draw on a total funding of some €20 million for several smart city applications. Most notable examples are project ELVITEN for electric vehicles[6] and project CITIMOBIL2 which installed the first driverless-bus pilot service in Greece[7];

In a recent article about Trikala, the UK paper *The Guardian*[8] noted, "Trikala citizens do not have to ask the local politician to get things done anymore. They do what they need electronically through the smart-city applications they have now available".

Figure 2: The autonomous bus experimental service vehicle in operation in Trikala.

Furthermore, worth mentioning are two on-going EU funded research projects that when completed will provide many answers and recommendations that will help the installation of smart-city applications in European cities. They are, projects C-MOBILE (Accelerating C-ITS Mobility Innovation and deployment in Europe)[9] and SHOW (Shared automation Operating models for Worldwide adoption)[10].

C-MOBILE involves a total of eight C-ITS equipped cities and regions in developing and testing smart city transport applications. The cities are: Barcelona, Bilbao, Bordeaux, Newcastle, Thessaloniki, Vigo, Copenhagen, and the North Brabant region. The applications tested, include: *Urban Efficiency*: Rest time management / Motorway parking availability / Urban parking availability. *Infrastructure-to-vehicle safety*: Road hazard warning / Emergency vehicle warning / Signal violation warning / Warning for pedestrians. *Traffic Efficiency*: Green priority / Green light optimal speed advice (GLOSA) / Dynamic eco-driving / Cooperative traffic lights for pedestrians / Flexible infrastructure (priority lanes) / In-vehicle signage (dynamic speed limit). *Vehicle-to-vehicle safety*: Emergency brake light / Cooperative (adaptive) cruise control (Urban ACC) / Slow or stationary vehicle warning / Motorcycle approaching indication (and other road users) / Blind spot detection & warning.

In project SHOW, a total of more than 70 autonomous transport real-life urban demonstrations are to be conducted and evaluated in 20 cities across Europe for 24 months starting in mid-2021. The project investigates technical solutions, business models and priority scenarios for the deployment of shared, connected, electrified fleets of autonomous vehicles in coordinated Public Transport (PT), Demand Responsive

[5] See for example: https://www.smartcity.press/trikala-smart-initiatives/
[6] Project ELVITEN, in: https://www.elviten-project.eu/en/about/
[7] Project CITIMOBIL2 – Trikala, in: https://cordis.europa.eu/project/id/314190/reporting
[8] https://www.theguardian.com/cities/2018/sep/04/trikala-greece-first-smart-city-dont-need-to-know-a-politician-to-get-something-done
[9] See: https://c-mobile-project.eu/
[10] See: https://show-project.eu/

Transport (DRT), Mobility as a Service (MaaS), and Logistics as a Service (LaaS) operational chains. All urban demonstrations of the SHOW project are user-led and aim at developing international standards and guidelines for Autonomous transport in urban areas. The cities in which the SHOW demos are deployed are: a) "Mega-city" full use-case applications in: Rouen, Rennes, Madrid, Graz, Salzburg, Vienna, Karlsrue, Mannheim, Aachen, Linkoping, and Kista. "Satellite" cities which will complement (with regard to technologies, business models, geographical coverage) the mega-cities: Brainport/ Eindhoven, Tampere, Trikala, Torino, Copenhagen, and Brno. Finally, there are the so called "follower" cities which follow the other ones without performing any demos in their territory. These are: Geneva, Brussels, Thessaloniki, and Ispra.

5. Conclusions

The idea of a smart-city, is – or should be - an urban area where information and telecommunications infrastructures create a unique environment aiming to ensure not only efficiency of operations but also sustainability, livability, and user friendliness all around. Making the smart-city of the future "green" and sustainable is perhaps the main challenge and all IT infrastructures and systems that are installed for a truly "smart" city operation should also safeguard its "green" and sustainable operation as well. Other challenges are to develop smart city systems and services that are truly integrated and that effectively harness the capabilities of advanced IT features such as artificial intelligence to manage and mitigate the risks involved. Such risks may be due to security issues (e.g. cyber-attacks) or extreme weather and so on.

Of equal importance are the behavioural and psychological aspects of living in a smart-city. The citizens will have to practically adopt new life-styles that will gradually change not only the way they move but also the way they live in these new environments. "Living apart together" (i.e. communicating via social media and other smart city socialization services) will probably be the new norm which will redefine the concept of "locality" in urban areas. Other similar changes will be in the whole system of urban goods deliveries that will be due to the advent of e-commerce.

Information Technology and the many cooperative Intelligent Transport Systems applications that are being tested and gradually introduced in our cities will certainly change them to become "smart" but at the same time we must ensure that they also remain "livable" and "humane". In other words smart-cities must comply with the need to combine their high technological development with retaining healthy lifestyles and sustainability throughout the system.

References

[1] Donnellan, B., Klein, C., Helfert, M., Gusikhin, O. (Eds.) (2019). Smart Cities, Green Technologies, and Intelligent Transport Systems, 7*th* *International Conference SMARTGREENS 2018, and 4th International Conference VEHITS 2018*, Portugal, March 2018.

[2] Pillai R. K., Ghatikar G., Seethapathy R., Sonavane V. L., Khaparde S. A., Yemula P. K., Chaudhuri S. (2019). SGW 2018 Compendium of Technical Papers: 4th International Conference and exhibition on Smart Grids and Smart Cities, *Springer Lecture Notes in Electrical Engineering 580*, Springer Nature Singapore.

[3] Zanella A.; Bui N.; Castellani A.; Vangelista L.; Zorzi M. (2014). Internet of Things for Smart Cities, *IEEE Internet of Things Journal*, Vol. 1, Issue 1, February 2014. DOI: 10.1109/JIOT.2014.2306328

[4] Tah J. H. M., (Editor). (2017). A Review of Smart Cities Based on the Internet of Things Concept, *Energies* 2017, *10*(4), 421; https://doi.org/10.3390/en10040421

[5] Sharif A., Li J., Khalil M., Kumar R. (2017). Internet of things — smart traffic management system for smart cities using big data analytics. School of Computer Science and Engineering, University of Electronic Science and Technology of China, Chengdu, IEEE 14th International Computer Conference on Wavelet Active Media Technology and Information Processing.

DOI: 10.1109/ICCWAMTIP.2017.8301496

[6] Qian Y., Wu D., Bao W., Lorenz P. (2019). The Internet of Things for Smart Cities: Technologies and Application. IEEE Network, Vol. 33, Issue: 2, March/April 2019, pp4-5. DOI: 10.1109/MNET.2019.8675165

[7] Burange A. W., Misalkar H. D. (2015). Review of Internet of Things in development of smart cities with data management & privacy. IEEE International Conference on Advances in Computer Engineering and Applications Ghaziabad, India. DOI: 10.1109/ICACEA.2015.7164693

[8] Rjab A. B., Mellouli S. (2018). Smart cities in the era of artificial intelligence and internet of things: literature review from 1990 to 2017. Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, May 2018, pp 1-10. DOI 10.1145/3209281.3209380.

[9] Borsboom-van Beurden J., Kallaos J., Gindroz B., Costa S., Riegler J. (2019). Smart City Guidance Package: A Roadmap for integrated planning and implementation of smart city projects, European Innovation Partnership on Smart Cities and Communities (EIP-SCC), Norwegian University of Science and Technology. In: https://eu-smartcities.eu/news/smart-city-guidance-package

[10] Behrendt Fr. (2016). Why cycling matters for Smart Cities. Internet of Bicycles for Intelligent Transport. Journal of Transport Geography, Vol 56, October 2016, Pages 157-164.

[11] Krishna R., Kummitha R. (2019). Smart cities and entrepreneurship: An agenda for future research, *Technological Forecasting and Social Change*, Elsevier, Volume 149, December 2019.

[12] Elhoseny H., Rjad A. M., Hassanien A. E. (2018). A Framework for Big Data Analysis in Smart Cities Springer Link International Conference on Advanced Machine Learning Technologies and Applications, pp 405-414.