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Towards an integrated process for digital transformation: 5G and beyond based smart transportation systems in cities and regions

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Abstract

Digitalization is transforming businesses and daily lives at an increasing rate. Cities and regions are going through a digital transformation process to develop and deploy a range of digital services covering most city functions and operations. The different operations are inter-dependent and are all constrained by new sustainability requirements. This paper investigates digital transformation in the context of future smart transportation systems in cities and regions and focuses on the situation in Finland. The paper analyses the current processes of urban design and planning, transportation planning, and digital infrastructure planning and brings them together towards a future process for smart transport system planning. The paper provides guidelines for the development of this interlinked future process for digital transformation and discusses related challenges. The integrated process highlights the importance of bringing together the traditionally separately considered urban design and planning, transport system planning and digital infrastructure planning processes by starting from shared values, goals and strategies that are built on sustainability principles. This requires the identification of a system owner, which has the overall responsibility of system development and operation.

1. Introduction

Digitalization is transforming businesses and daily lives at an increasing rate, accelerated by the COVID-19 pandemic. Work, education, and many leisure-time activities, such as shopping to mention a few, have gone through rapid digitalization during the pandemic. Cities and regions are in a strong transformation process to develop and deploy a range of digital services. These digital transformation processes will cover most city functions and operations, like healthcare, education, residency, energy, water supply, transportation, and other public services and their private sector counterparts as cornerstones of modern society (Bibri, 2018; EC 2021). To realize successful digital transformation, smart city strategy, planning processes and management need to be unambiguously defined and properly implemented throughout the involved organizations. Otherwise, digital transition and the development of digital services may scatter in multiple discrete sections without interoperability between them. During the past few years, a vast number of pilots have been conducted to develop new smart city digital services. A common feedback and experience about the pilots has been that even successful pilots did not lead to real-life implementations in the city environments (van Winden and van den Buuse, 2017). The reasons for this have not been always clearly recognized, but there can be issues like the lack of process ownership, weak identification of required stakeholders, technical deficiencies, lack of scalability or economic challenges. Considering typical city functions, like energy, water supply or transportation, there is always a responsible organization to operate and develop the system (Oliveira & Campolargo, 2015). For the development of transportation system, the key stakeholders in addition to transportation planning experts are specialists of urban design and planning (Jurva et al. 2021).

At present, urban design and planning and transportation system planning are operated in close co-operation due to their statutory character and strategic role in regional structure and urban form (Jurva et al. 2021). In addition, the urban design and planning processes are cornerstones for democracy, the community and the elected city councilors should approve the plans. The digital transformation on the other hand, is a megatrend with no identified process owner, single authority, clearly defined or statutory processes. It will mainly be developed by market-based initiatives, which set

demands for existing processes. The implementation of digital transformation to urban design and planning and transportation planning processes calls for innovative process management and new approach to synchronization of the development and construction. The planning process requires co-operation with stakeholders including authorities, regulators and companies, which were earlier not involved in the transport system planning process, which were identified in (Jurva et al. 2021).

To enable the development of future digital transportation system, the digital infrastructure like 4G, 5G and beyond mobile communication systems as well as IoT sensor systems and data platforms play a fundamental role (Shafi et al., 2017; Ali & Nencioni, 2021). Digital services are typically highly data intensive, meaning that developing attractive and sophisticated transportation services involves the generation of high volumes of data by various sources, collecting this data and processing it to offer new services (Caragliu & Del Bo, 2019). By ensuring availability of real-time data used by transport-focused applications, the resulting applications are more powerful in serving better the needs of versatile modes of transportation and optimizing various resources usages as constrained by increasing sustainability requirements.

The need for digital infrastructure evolvement as a service enabler is still a rather new necessity compared to traditional entities of urban design and planning and transport planning (Matt et al. 2015). Cities can be confused about how to ensure the development of ICT infrastructures including e.g., 5G, IoT and computing infrastructures. Typically, the cities rely on the national mobile network operators (MNOs) for connectivity services even if there can be service gaps, or the mobile network service is not homogeneous throughout the city or region. When planning a digital smart transport system based on mobile communication technology, such as 5G, the citizens primarily assume that the services are reliably available all around their region of movement. Partly due to this reason, in recent years, studies have been conducted about complementary models of developing 5G wireless communication networks (Matinmikko et al. 2017). These studies have visioned that novel actors, like local micro operators or vertical-specific operators, could boost the spreading of 5G and beyond technologies in cities and regions and thus supplement the services of national MNOs via local deployments of mobile communication networks (Matinmikko et al. 2017; Jurva et al. 2020b). Related to this vision, it is important to consider who the stakeholders of local or vertical-specific network deployments are and if cities and regions should adopt a role in this development in order to drive the development of smart transport services. The responsible organization in cities may not exist or they might be lacking the need competence development, when it comes to digital systems.

The development of IoT sensor systems and data management infrastructure as new entities in the context of city planning assume considerations about who are the actors to development such infrastructures (Jurva et al 2020; Jurva et al 2020b). In the past there have been many of realizations of sensor and data systems conducted together with the transport system development (Oskarbski, 2011). Typically, they are cameras and sensors to monitor and update situational awareness. However, it is foreseen that the amount of sensor and data infrastructures will be highly increased due to the development of smart transport systems (Pop et al., 2020; Neilson et al., 2019). Scalability of the systems has been the bottle neck will be a key success factor for the future to develop those systems. Therefore, it will be a topical question to cities and regions, how to develop and operate these systems.

Typically, smart transportation system planning is conducted on city or regional level but to be fully operational system it also requires national co-ordination, which needs to be included in the planning process. This requires several strategic decisions that should include estimations of required competence for different development areas of digital transport system. When the organizational capability is ensured, the next step is to define the digital transition co-operation processes to develop the smart transport system. The processes must adopt a systematic approach including specification of desired transport services instead of randomly chosen development trials of various commercial solutions, which probably results into system without inter-operability between different elements of the transport system. This also requires review and alignment of the existing processes of urban design and planning and transportation system planning with the new process of digital infrastructure planning. When the organizational capability exists and processes are accurately defined, the project management for digital transform of transport system can be nominated

When developing digital transportation system for a smart city, the processes of urban design and planning, and transport system planning will be complemented with digital infrastructure planning of 5G/IoT networks, data management capabilities, platform and application development. To develop new digital transformation strategies the alignment of these three separate processes becomes critical as discussed in (Jurva et al 2021), where stakeholders for this development were identified. This paper aims to answer the following research questions:

- 1) What are the current processes of urban design and planning, transportation planning, and digital infrastructure planning and their relations in a smart region? How are they currently managed in local, regional and national levels?
- 2) How to bring together these three domains towards future processes of transport system planning? Which stakeholders and competences are needed?
- 3) What are the strategies of developing local and regional digital infrastructure? Which are the pros and cons of different options?
- 4) What are the requirements of smart transportation to digitalization process?

The rest of this paper is organized as follows. After summarizing the research method in Section 2, we review the literature on current processes of urban design and planning, transportation planning and digital infrastructure planning in Section 3. Section 4 provides guidelines for the development of the new interlinked process that brings these three processes together for future transport planning in smart city and region. Section 5 presents discussion and conclusions.

2. Research Method

The research in this paper is conducted as a multi-disciplinary co-operation effort that brings together experts from transportation, urban design and planning, and ICT research fields. The research focuses fully on the situation in Finland and notes that the processes are different in different countries. The research includes reviews of existing regulations related to ICT, transport an urban design and planning, and related literatures. The research uses workshops, webinars, meetings, and interviews with the identified stakeholders for data collection. A total of 18 events have been organized in 2020-2022 with participants from research, companies, city officials and authorities for data collection. Eight workshops and meetings were organized with the transportation development program of a major city in the north of Finland. Moreover, monthly working group meetings of researchers presenting different angles of transportation like system planning, connectivity, vehicles, environment, and business were conducted in 2020-2021.

The development of smart transportation systems requires that the current processes of urban design and planning, transportation planning, and digital infrastructure planning and their relations in a smart region are first defined. This involves the identification of the stakeholders that are required at minimum to the system evolvement and operation (Freeman 1984) including specifying their roles and responsibilities. It is also vital that each stakeholder will commit in the cooperation through common processes. Additionally, the current status of existing the infrastructure including transport, city/region and ICT infrastructures needs to be analyzed. At the next phase, the new joint ecosystem needs to specify the common targets of the digital transition project from all three sectors including, e.g. technical, operational, business and service aspects. This requires also the identification of a system owner, which has the overall responsibility of system development and operation.

Until now, research and development projects of ICT systems have strongly prioritized technical characteristics and advances of systems. The importance of technological evolvement is evident due to the increasing role of ICT systems in all domains of society (EU, 2021), which has set continuously new requirements to system parameters like data rate, latency, capacity and connectivity. However, discussions have recently arisen about more human centric approaches of the research and development of technical systems (Haddington et al., 2022). One of the reasons is that technological development has been so fast that it has brought challenges to people to adapt and deploy new technologies. Technological development is many times not the limiting factor of societal development but the human perception and capability to adopt new systems. Similarly, a typical process to develop infrastructures has been focused on the governance and operational aspects due to reasons like effectivity and cost.

In urban design and planning procedures the human centric approach is implemented in the process. The built environment is the platform for diverse services which people need and use directly or indirectly. Therefore, people have several roles at the same time: resident, customer, worker, visitor etc. In Finland the stakeholders must be identified in the beginning of the planning process. The interested parties may have the opportunity to participate in preparing the plan, estimate its impact and state their opinion on it, in writing or orally (Land use and Building Act, 132/199, section 62). The interested party is normally a stakeholder who already operates in the area, i.e., the planning process and the new development will evidently have an impact on the stakeholder's current situation. Any development in the built environment may profit or harm the existing stakeholder's situation, therefore, the interested parties will assess the impacts accordingly. The infill development will also invite new stakeholders, who cannot be identified during the planning process. The new houses, roads, infrastructure etc. will be built in keeping with the valid plan. The new

development will be marketed to customers, who would move to the area. The customers should invest money in houses and dwellings, change their living environment and mobility habits. They also need to integrate into the existing community. Hence, the clients will have provisional interests, which the existing stakeholders may not have. The investors should make proper market analysis and identify customers for each project, since the project needs to be economically profitable. The gap between planning process and realization of the plan is critical for smart city development, since the human aspects will change in time; the interest of the existing stakeholders (interested party) vs. interest of the new stakeholders (customer). The investors (commercial or public) need to decide how to integrate economically profitable smartness to new development and to new services. They should also analyze how and on what grounds they should upgrade existing built environment for existing community.

3. Literature review on main processes

Smart city transport system development involves several domains in addition to the transport sector itself. At least, urban design and planning as well as ICT are involved, while the linkage of these three domains still remains little-researched (Jurva et al. 2021). In the following, we review the current processes of urban design and planning, transportation planning, and digital infrastructure planning and their relations in a smart city describing how they are currently managed in local, regional and national levels.

3.1. Urban design and planning process

In Finland the national urban design and planning processes are defined in Land Use and Building Act (132/1999) and in Decree (895/1999). Since the 1st of January 2000, the municipalities and the cities have used planning monopoly in developing the future urban structure to meet with the future needs and to provide options for businesses and public investors, as well as to protect existing natural and cultural values. Any change in our living environment may cause diverse impacts for the stakeholders, therefore the operations taken are regulated and the roles of the actors executing operations are identified. The statutory planning process is for valid reason open, participatory, and democratic. The Constitution of Finland (731/1999) provides rights and responsibilities which have an impact on urban design and planning processes, most relevant of those are 1) protection of property (section 15), 2) freedom of expression and right of access to information (section 12) and 3) responsibility for the environment (section 20). The planning process consists of clearly defined steps and their deliverables: 1) initiative, targets and objectives of the plan (*participation and assessment scheme*), 2) planning preparation (*drawing up a draft*), 3) planning proposal (*drawing up a proposal*), 4) decision of approval (*approval by the political body*) 5) appeal 6) plan in force (*publicizing the approval of the plan*). Since urban and design process is about managing conflicting interests and the aim is to reach democratic consensus about the future regional, community and urban structure, the outcome is the plan i.e., the map including a key to the symbols used and written regulations. The stakeholders are defined in legislation (section 62) in addition, they must be listed in participation and assessment scheme, The stakeholders are: 1) state authorities, 2) local authorities, 3) NGOs, 4) landowners, 5) corporations and 6) interested parties i.e., those on whose living, working or other conditions the plan may have a substantial impact. The local authority must have a planner who will manage the planning actions.

In April 2018, the Ministry of Environment in Finland set up a parliamentary monitoring group and working group to prepare a comprehensive reform of the Land use and Building Act, which consisted of partial reforms of sections and new sections resulting in fragmented and complex structure. The Act did not respond to future challenges in new operational environment anymore. In 2018 the multidisciplinary stakeholder group and five subdivisions were set up to support the process and the digitalization and customer oriented working group was nominated. In October 2021 the Government Proposal of the new Planning and Building Act was open for comments. The ambitious goals in the revised proposal were carbon neutrality, biodiversity, streamlining construction, quality and digitalization. The process and the new sections did not appeal to stakeholders, since the feedback was crushing: most of the 550 comments and statements were against the proposal. The Ministry had to split the reform in two parts in 2021: the revised sections regulating building and building permits would be removed from the Act. The new Building Act would be prepared, and the digitalization of the planning would be the main objective of the reform of the Land Use Act. Despite of participatory process and interaction between working groups, the parliamentary preparation failed to achieve its goals. The process itself was criticized: the quantity of the interaction did not compensate the quality of the participation. The digitalization of the planning process remained as the main objective for urban design and planning.

The digital transformation will affect the way to manage, process and use information on the built information. At the moment, the abundant and important information about the built environment is scattered, incoherent and difficult to use. The Ryhti project, which is preparing a nationwide information system for built environment, focuses on 1) interoperable information accessible to users throughout society, 2) much less overlapping information is collected and information is always up to date, and 3) high-quality information enables better decisions and promotes business and services.

3.2 Transport system planning

Transport system planning is continuous long-term strategic planning that reconciles the future needs of transport and land use regarding people and business as users of the system. More broadly, transport system planning is part of the transport system work that enables continuous monitoring of the transport system and responding to changes in it as quickly as possible. Transportation system work is carried out at different levels. At its widest extent, it is a national level transport system work, which can be attributed to political alignments, such as the Government Programme, the preparatory alignments of the Ministry of Transport and Communications, as well as the various expert alignments of the Finnish Transport Infrastructure Agency and the Finnish Transport and Communications Agency (Traficom). More narrowly, transport system work can be thought of as regional cooperation between actors, guided by mutually agreed objectives and jointly drawn up plans. Transport system work may include, for example, road safety cooperation, public transport planning cooperation, joint pre-surveys, and the involvement of state transport authorities in municipal land use planning. The transport system plan and the monitoring of the implementation of the plan are key components of transport system work, as the plan gives the framework to the actual work.

Transport system planning is carried out at national, regional, and municipal level. According to the Act on the Transport System and Highways (503/2005), the national transport system plan is made for 12 years at a time and updated every four years when the government changes. The first nationwide transportation system plan was completed in 2021. The aim of the plan is that the transport system ensures accessibility throughout Finland and responds to the needs of livelihoods, employment, and housing (MINTC, 2021). It includes all modes of transport, personal and freight transport, transport networks, services, and cross-cutting themes of the transport system, including digitalisation. The National Transport System Plan also looks at Finland as part of the international transport system. The National Transportation System Plan includes a 12-year operational programme of state and local government measures, comprising both operational and investment measures, as well as a government funding program.

One point in the operational programme is the development of a transport system analysis, that is, a strategic level overall picture of the transport system. Transport system analysis is intended to become a key tool for transport system planning at national and regional levels, providing comprehensive information for transport system decision-making (Traficom, 2021). Monitoring the goals of the national transport system plan is also part of the transport systems analysis. In practice, monitoring is carried out by means of a purpose-developed monitoring instrument, which compiles key indicators of the situation in the transport system to examine the implementation of the objectives of the plan.

The national transport system plan provides guidelines for new regional transport system plans. According to the Act on Regional Development and the Administration of Structural Funds (7/2014), initiating the planning process of the regional transport system plan and leading the related cooperation is the responsibility of the regional councils. Several regions have updated their plans to align with the nationwide plan. The regional transport system plan includes a review of regional specifics and the interest supervision related perspectives to justify the region's funding needs for nation-level planning. Regions may also develop common transport strategies among several regions. These plans are located between regional and national transport system planning and their purpose is two-way. The strategy identifies and aligns the common needs of the regions and communicates them at national level. On the other hand, it interprets national choices and alignments that will be implemented in regional planning.

Transport system planning at municipal level often addresses typical urban traffic challenges, such as controlling traffic growth and environmental disadvantages and increasing the share of sustainable modes of transport. In particular, planning should take into account the interconnection between transport and land use planning, as well as the roles and cooperation between different modes of transport. Transport system planning at municipal level is often linked to municipalities' own or local master planning work. More precise land use planning will finally determine how the development goals set out in the transport system plan will be realized. The land use planning process determines area reservations for traffic and other land use.

Need of communication will increase in future transport system due to the reason that vehicles will generate and transmit data as well as receive, process and share information with other vehicles and infrastructures. The communication happens partly directly between vehicles (V2V) having probably the highest requirements of communication performance. However, vehicles will be also communicating with the surrounding infrastructure (V2I), pedestrians, bicycles or road workers. In this communication 5G technology will play a key role (). Part of the communication is delay sensitive, which means that network delays must be extremely low compared to previous 4G and earlier network technologies. To minimize the delays, the wireless infrastructure has to offer also powerful data processing capability with distributed edge computing. These demands set high requirements to the telecommunication infrastructures which need to be developed to fulfil the needs. This applies also in the rural areas where wireless network services may still suffer from serious degradation of service. The following chapter introduces the current principles of digital infrastructure planning by national operators, which probably require new approaches when the smart transportation systems develop.

3.3 Digital infrastructure planning

Digital infrastructure planning involves data and connectivity systems and solutions, which presents a complex network of solutions. For simplicity, it can be considered to consider two sides: mobile communication networks and IoT sensor systems that are both important for smart transport systems. Current processes to develop digital infrastructure are typically based on commercial terms. Mobile communication infrastructure in cities and regions is taken care of by commercial market actors, namely mobile network operators (MNOs). Different generations of mobile communication networks and most recently 5G networks are in Finland deployed by three nation-wide MNOs which have gained exclusive access rights to spectrum from the regulator. Network planning processes are strongly based on MNOs' business plans, following the coverage obligations set in the license agreements. Often the initiation of the planning process includes analysis of the market potential, which usually means to develop mobile communication networks first in areas, which are highly populated like city centers, traffic hotspots, shopping centers, wealthy populated and residential areas. The planning process for the new 5G technology can be driven by studying existing 4G network traffic profiles based on existing subscriber base, from where the most active users can be recognized. Another driving factor of the 5G network planning process is the existing network grid and topology including the existing sites of network infrastructure elements, which the nation-wide MNOs have developed through the past years when deploying the earlier generations of their mobile communication infrastructure. A third major factor influencing the 5G network planning process is the budget, which the MNOs have allocated for wireless infrastructure development. In Finland, spectrum licenses costs are comparably low, which allows the MNOs invest in the networks. After the completed planning process the network will be launched to serve subscribers. All the nation-wide MNOs do not yet have similar practices and policies, which typically causes degradation or even lack of services in certain areas of cities and regions meaning that subscribers may need to change their service provider depending on their home, work or leisure time locations.

Utilizing the grid based on 4G network topology may generate challenges to reach homogeneous service quality due to the fact, that 5G networks are utilizing higher frequency bands (namely 3.5 GHz and 26 GHz), which results in weaker signal propagation in the surroundings, i.e. meaning smaller coverage areas. Thus, if the network grid is planned for lower 4G frequency bands (up to 2.6 GHz), it is possibly not dense enough resulting into gaps of the service coverage in the higher frequency bands. Considering the requirements of smart transportation on the digital infrastructure, it is expected that the mobile communication service coverage is available all over, where the digital transportation services are offered. From this aspect it needs to be considered if the existing processes of national telecom operators need complementary methods and processes. An interesting feature in spectrum licenses, which are the permits for the MNOs to deploy mobile communication networks, is obligations part where the MNOs in Finland are required to cover population density and also roads (MINTC 2016).

Concerning the development of IoT sensor technology networks the planning processes are mostly based on the requirements coming from current infrastructures of city functions like energy, water management, transportation or other services offered by cities and regions. Based on special needs of these functions they have developed sensor networks together with the infrastructures. What comes to transportation infrastructure, planning and integrating IoT technology ensures, that there is data available to improve situational awareness of the transportation infrastructure. Assumingly, typically the planning process is strongly based on needs to monitor the functionality of the infrastructure itself with certain parameters like traffic flow, road conditions, accidents or weather conditions.

4. Building an Interlinked Future Process

Next, we proceed to build an interlinked future process for digital transportation planning in future smart city and region that brings together the processes of urban design and planning, transportation planning, and digital infrastructure planning. Figure 1 illustrates the digital transformation process of smart transportation systems. The process of developing local and regional infrastructure starts with the evaluation of the existing processes to support each other in terms of contents and alignment with each other. Urban design and planning and transportation planning probably set requirements to digital infrastructure planning in terms of land use planning, permitting, visibility, availability and performance. On the other hand, digital infrastructure planning process requires to deploy new planning systems to interoperate with the existing systems. Moreover, the data management system for refining and sharing the transportation data needs to be deployed with interfaces to current systems. These phases of the interlinking process probably require new competencies to be developed in the city planning organizations.

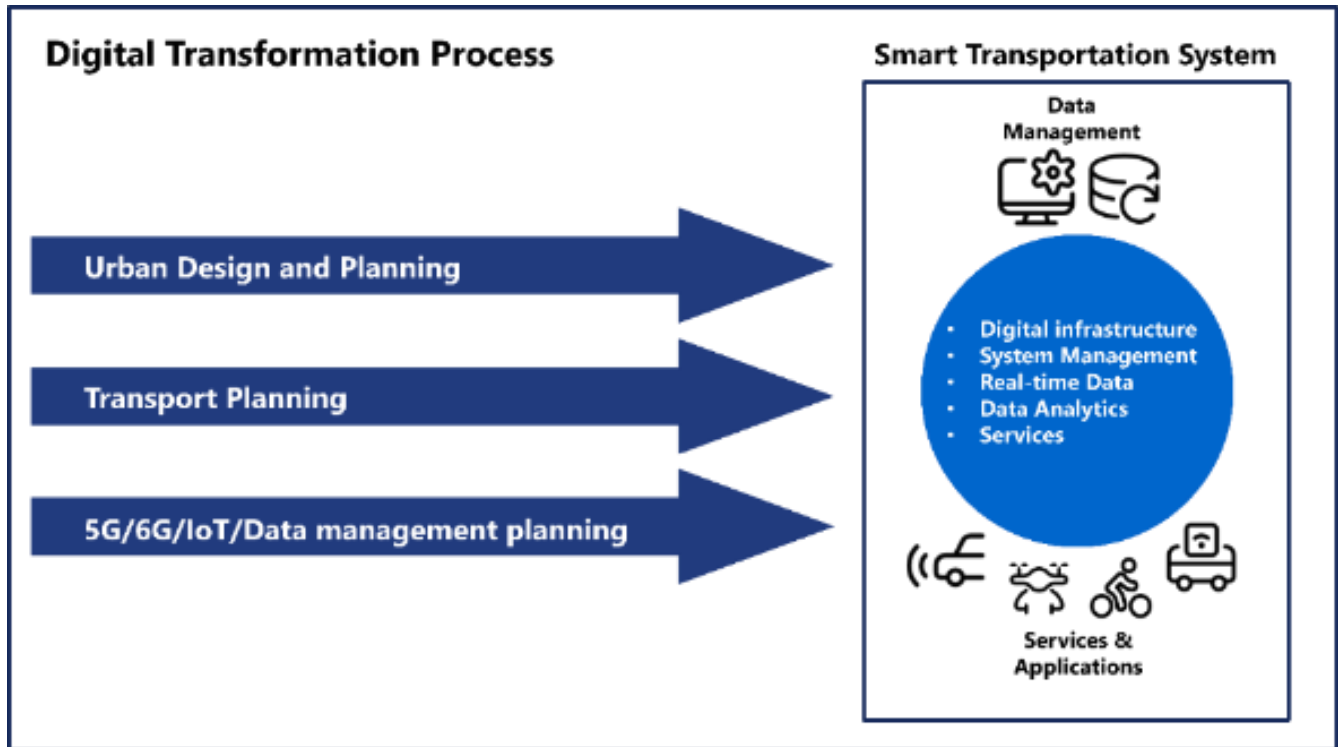


Figure 1. Digital Transformation Process of Smart Transport System

4.1. Integrated trends

Extensive utilization of ICT solutions and services will trigger lots of development enabling reform of transportation. Each of the transport modes will probably benefit from digitalization by special services developed for those but from the inter-operability point of view it is propounded, that a system overview would be adopted in the digitalization of transport services. Considering public transportation, it is essential to ensure e.g. applications for travel chains, easy payments, connectivity and other wireless services underway. Moreover, the public transportation must be compatible with private transportation meaning effortless changes of mode in the transportation nodes meaning availability and real-time data about parking lots, electric charging or hydrogen gas stations. Despite of fueling, private cars will be developed increasingly more software controlled with various services like entertainment, well-being, guiding and maintenance. That assumes high volumes of data transferred to other vehicles and to infrastructure. Pedestrian and bicycle transport modes will be similarly evolved towards digital services. Various information systems have been developed for them to offer real-time data about weather, route condition and traffic flows. When it comes to logistics, it is anticipated that future services will be developed based on platforms composed of clusters of drones to deliver goods to citizens or even passenger drones will appear. The ICT technology will enable numerous novel innovations of future digital transport system. From the urban planning point of view this assumes dense and dependent wireless 5G and beyond infrastructure to be developed in cities and regions.

The Ministry of Environment started in 2021 to define a desired scenario for land use in Finland until 2040. The work will be based on the four scenarios for regional development until 2040 requested by the Ministry of Economic Affairs and Employment of Finland (Sotarauta et al 2021). The main issues in future development are: 1) how to create world class centers of excellence in Finland, and b) what kind of roles would the regions have in future (Sotarauta et al). The aim is to create a modern tool, in which baseline data, (1) a situational scheme would provide real-time and reliable data of built environment and regional structure. The national and international region and community structure should be taken into account in the baseline analysis. Based on the updated situational data (2) the scenarios of future development could be created. The process would result in (3) development plan /policy paper for each Government. This rolling process would follow national election cycles and would be prepared in parliamentary process. The aim is to create a comprehensive tool which would help in tackling complex planning problems and which could be implemented in agreements and strategies. The stakeholders' role is central in this process. The regulation and the investments have a huge impact on the regional development. The regulation (EU, the state) is a precondition for long term development and will provide equal development targets for the regions. Regulation provides new actions for climate changes and sustainable development. Smart transportation development is dependent on stakeholder's (public or private) capacity and will to invest in the regions. The investments invite businesses, activity and excellence in region. The agreements which the cities make with the state (such as MAL-agreement in Finland) are the cutting edge for development: the cities have primary access to investments while the other cities need to rely on normal budgeting and other attraction features in the region. In case the region lacks investments, or the investments may be delayed, the region may suffer from inequality, inaccessibility and even economic recession. The Finnish Transport Infrastructure Agency provides an investments programme for the Parliament in Finland. The investment programme supports Liikenne 12 principles and MAL development. The investments are mostly targeted at railroad and road investments in the regions which already have good development potential and rising population i.e. Southern Finland (Valtiovarainministeriö 2021). The investment programme was strongly criticized by other regions. In addition to economic development the regions may benefit from *glocalization* in which international networks and local development are interlinked. Digitalization may also benefit from international development which does not require national or EU-regulation or investments.

Transportation has been defined as one of the key verticals in the sketched national digitalization roadmap 'Digital Compass' of Finland following the European level Digital Compass (EC 2021), which defines targets and metrics of the digital development until 2030. Target is to develop data infrastructure and practices a.k.a. data spaces based on open standards for data-based value creation. The metrics to evaluate the achievement of targets have been defined as the volume of investments of companies to data economy. This applies to both domestic and international companies. Transportation is determined to be one of the domains where data space is to be developed. The roadmap is based on e.g. Liikenne12 (Traffic12) vision defined by the Ministry of Transport and Communications.

Despite its significant role in city planning, urban planning and design sometimes faces phenomena, in which it cannot influence or direct the development but needs to adapt in global trends. Examples of such trends are electric vehicles, travelling and retail. The global car industry has enormous investments in electric vehicles, which requires to deploy nationwide charging infrastructure for electric cars. This needs to be considered also in land use planning of cities and regions to ensure sufficient capacity of charging electric vehicles. Maybe the biggest challenge will appear on regional level, which may contain also rural area. Sharing economy has been applied in travel industry enabling private persons to offer their apartments to travelers, which may affect in the need to build new hotels. This may release land to be planned for other purposes. Moreover, web-based shopping has become very popular which affects retail and logistics. Some premises of retail are not need any more, but the land can be used for other needs. In the previously defined cases urban planning and design need to adapt in global trends in land use planning.

All city and region developments are nowadays driven by stringent requirements stemming from sustainable development. Sustainability has become the major driver in all sectors of society. Especially, the countries' target to reduce carbon emissions to combat climate change has become the new criteria for many sectors, which calls for renewal of traditional mode of operation. Joint green and digital transformation is thus a key driver for the new development that aims at reduction of different sectors' environmental impact.

4.2. Proposed integrated process

Smart city is usually referred to as digitalization of processes and services, which are traditionally conducted in silos and in fragmented projects and pilots without identifying dependencies between each other. Moreover, a proper stakeholder analysis is many times missing before the execution of pilots resulting that the pilots are rarely continued

as new digital services in authentic city environment. The principle of digital processes and services is that they are always available and they are based on continuous access to real-time data, which makes them attractive to use.

To adopt a holistic view and to improve the development processes of Smart City services a new approach has been under study. The concept is called MetaCity, which means a novel method to first evaluate the existing processes and their suitability to digital transformation processes. Reviewing of processes assumes to dig in the very basic activities and processes concerning 1) platform (built environment), 2) services, 3) infrastructure and 4) financing and actions of processes to assess their role, function and impact in the refreshed digital transformation process. In case of inappropriate methods and processes are identified, it requires to renew them based on requirements coming from the digitalization of smart transport system. This may lead to integration of processes to break down the silos and to motivate the specialists in intensive customer-oriented cooperation to develop unforeseen digital services, experiences and sentiments.

In the new MetaCity model, everyday services are also based on social networks and virtual environments, which have been more familiar from entertainment and game applications. The services are developed based on game engines and immersive technologies, through which everyday service environments will be increasingly 3D surroundings. Moreover, the user is able to move from one service environment to another environment without visiting the physical world between them. A MetaCity platform will enable to develop entire service chains. Immersive services will be applied also in the smart transportation system, even if use cases are still under development.

To develop sophisticated smart transport services, physical development environments of high standards need to be set up, which will be used to pilot integrated processes and updated responsibilities of stakeholders. On top of these platforms, it is possible to develop proof-of-concept trials based on minimum viable product (MVP) and platform economy approach. After successful pilots, the scheduling of market-oriented service development phases can be planned. To run the services, it is important to identify the stakeholders and customer segments to be able to develop competitive services, which will be in continuous development cycle based on follow-up and feedback from users and continuous data analytics. Finally, running the cycle of service development requires strict management and financial control. This approach to smart service development is illustrated in Figure 2.

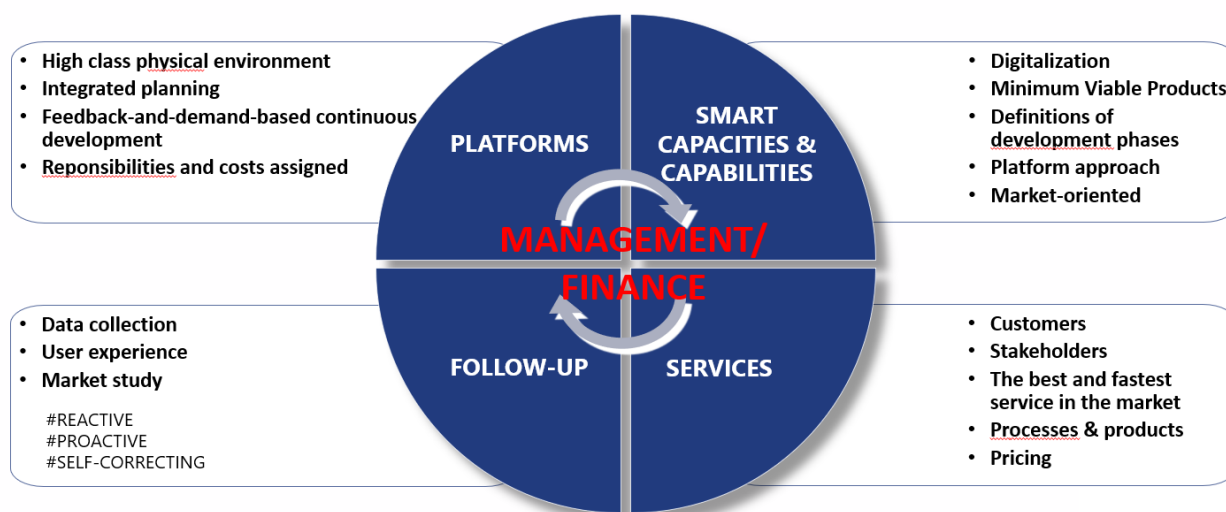


Figure 2. Approach to smart service development.

Figure 3 outlines the development of a joint process that brings together the traditionally separately considered urban design and planning, transport system planning and digital infrastructure planning processes. This development starts from shared values, goals and strategies that are built on sustainability principles. After that, the stakeholders for the joint process need to be identified and the joint process needs to be defined. This requires also the identification of a system owner, which has the overall responsibility of system development and operation.

To further evaluate the success of interlinked processes and maturity of the resulting smart transport system, it might be relevant to develop a special maturity assessment model of the smart transportation system. The model will help to evaluate the status of interlinked processes, grade of co-development, commitment of management and innovation capability of service development. The model also enables to compare the ‘smartness’ of transport system to other locations nationally and internationally. Typically, maturity assessment model is divided in analyses of sub-areas, which are required for successful development of smart systems. Each of the sub-areas contains questions to define the status of development. Moreover, the questions help to develop the sub-area further towards advanced smart transport services.

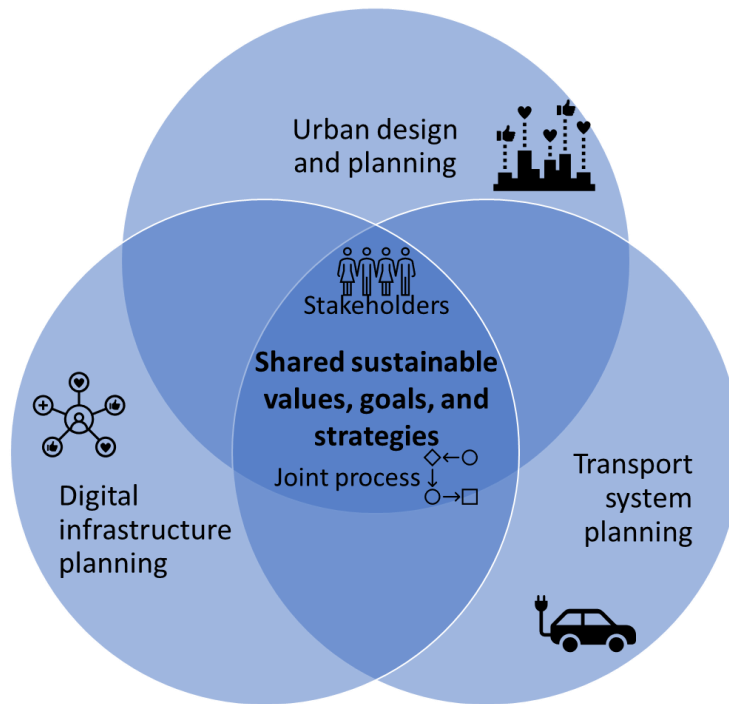


Figure 3. Development of a joint process for smart transport system planning.

4.3. Challenges

When the processes of urban design and planning, transport planning and digital infrastructure planning have been interlinked to a common future smart transport development process, we need to nominate the process owner to lead the process execution. Managing the process requires to adopt a holistic system view of the smart transport system. Compared to previous, this may cause challenges due to big changes of transformation of transport system. Considering the transport function in cities, one could assume that digitalization of the transport system will be managed by transport specialists. However, a key focus in the development of smart transport system should be in the innovation of sophisticated services for each transport mode, which together compose the entire mobility system for any needs of citizens. Subsequently, some competence of digital systems and their applicability to transport sector is required in the development process. On the other hand, considering the larger context of digitalization of all functions of cities it would be preferred to have a special organization to look after the city or area level digitalization. Preferably this organization would be an integrated team of multi-professionals and experienced specialists from various functions to ensure interoperable system through the verticals. Generally, the transformation process probably requires that city organizations acquire new competence areas and skills to be able to take strong managerial role in the development of smart transportation digital services. This setting will ensure, that the city officials are leading the development, but it is not subordinated to pure business interests of commercial actors.

The stakeholders’ development goals are implemented in the built environment through urban design and planning processes. As mentioned earlier the planner should identify the stakeholders in the very beginning of the process to be able to coordinate diverse development goals and planning issues. The participatory process provides opportunities to modify the process, accordingly the identified stakeholders should bring expertise to the process. In case the smart city or smart transportation development is not totally, or even partly allocated to any stakeholder, the planner cannot promote the expected development, and the policy makers cannot support the expected outcomes in the decision-making

process either. Due to very long timespan from land acquisition to final community structure, the critical steps of the smart transportation and smart city development should be 1) identified in the stakeholders' strategies, 2) implemented in processes, and 3) conceptualized in the context of built environment.

4G networks can fulfill many of the current requirements of smart transportation system excluding some delay sensitive communication needs, which will be conducted directly between vehicles and not through the mobile communication infrastructure. Subsequently, even if the spectrum license terms of 4G networks require to deploy networks in all major roads in Finland for example, many rural roads are still suffering from low connectivity. This will bring the challenges to develop nationwide smart transportation system due to the fact, that MNOs are probably not willing to deploy 4G or 5G networks in rural areas due to weak business potential. Therefore, the public authorities need to find alternative options to cover roads in rural areas in addition to coverage obligations. A major challenge will occur, if a large number of devices use data intensive applications that create heavy uplink traffic. The same issue is faced in city regions, when it comes to the deployment of data transfer infrastructures like fiber networks. Currently, cities are typically leaning on commercial actors to deploy fiber network infrastructures. In harnessing the most beneficial characteristics of 5G technology like high data rates and low latency, the existing approach may lead in situations where large areas of cities are not covered with high capacity 5G networks limiting the development of smart transport system. To fulfill the requirements of smart transport system it may assume a new approximation from cities and their ecosystems. Otherwise there appears a high risk of inequality between areas, where some citizens have access to sophisticated transport services, when the others are suffering from a large variety of smart digital services. Unequal access to fast digital services does not only concern rural areas, in urban city structure market-based broadband developers may have totally opposite scenario for adjacent neighborhoods.

The state will play a significant role in creating capabilities and capacity. In Finland, the state will invest money to regions and cities which commit to mutual interests and development plans. The municipalities and the citizens do not have equal access to smart transportation, if only the most populated regions or cities can make agreements with the state. The rural areas and smaller cities cannot invest in infrastructure themselves, which may result in insufficient services and fragmented infrastructure. This may also lead to project-based development, in which new innovations emerge in spatially and temporally defined processes. The process owners can be identified during the project, but the situation is different after the project ends. On the other hand, the state will set new demands for the municipalities, cities and regions by approving new policy papers and legislation. The Finnish Government just recently approved the decision of principle for promotion of multi-location-based work, studies and living (Valtioneuvosto, 2022). The aim is to develop primarily a market-based digital infrastructure; subsidized development, which is needed in rural areas, would be the very last choice. Even if the access to broadband networks and fast (over 100 Mbits/s) connections varies a lot within regions and within cities, digitalization is regarded as an asset which will inevitably modify our everyday life. The multi-location-based working would take place in rural areas, which on the other hand will not provide markets for market-based digitalization.

4.4. Including sustainability perspective

Sustainability has become the single most important driver in societies to reduce the carbon emissions to meet globally agreed targets for combating the climate change. Sustainability has no single owner but is spread to all sectors of society creating overlapping and possibly conflicting agendas among sectors. Sector specific regulations are emerging with specific targets to cut emissions. This makes the topic highly multi-disciplinary and complex as developments in one location that positively contribute to reaching sustainability targets can negatively impact another topic. The siloed development where each sector defines its own sustainability impact without understanding the complex interrelations of sectors can lead to sub-optimal solutions.

The ICT sector is a good example of this development. Its enabling role to cut emissions in other sectors (handprint) has gained significant more attention than the ICT sectors own sustainability burden (footprint). The use of ICTs keeps increasing, resulting in ever increasing energy consumption among others, while efforts should focus on the reduction of the burden and not increasing the consumption.

Additionally, sustainability is not only about reduction of green-house gas emissions but involves societal aspects such as equality. Digital transformation can lead to increased equalities, simply by not being available for all at the same level depending on the location.

5. Discussion and conclusions

This study has highlighted the importance of bringing together the currently separate planning processes for digital transformation development to renew different sectors' operations towards sustainability. We have focused on future smart transport systems and realized that in addition to transport system planning, also urban design and planning and digital infrastructure planning are vital, and all three must be considered jointly. By identifying analyzing the existing processes, we have identified the importance of stakeholders' roles in the separate planning processes including internal and external stakeholders. When these processes are attempted to be brought together, there is a need to clearly define the new processes and their leaderships. Digitalization results in a complex new setup where the existing stakeholders face new situations which go beyond their traditional expertise areas, opening the door for new stakeholders to influence the development. This requires the identification of a system owner, which has the overall responsibility of system development and operation.

ICT development is highly market-based activity where commercial stakeholders deploy digital infrastructure based on demand. At the same time, societal developments emphasize equality and equal opportunities despite of location, which contradicts with commercial ICT developments. To solve the mismatch, here is a need to change the view-point make digital services available for everybody, which calls for renewal of traditional planning processes.

A novel MetaCity approach has been described where the service development of smart transport system is based on strict analysis of existing processes of urban planning and design and to evaluate their suitability in digital transformation processes. When the processes are developed in cooperation by cross-functional specialists, the outcomes may result in astonishing services. The MetaCity model also includes increasing utilization of immersive technologies, which may offer attractive services also in the transport sector. Even if high technology plays a key role in the development of future transport services, the end-user and customer experiences must be raised as driving factors of service development maintaining the approach of human driven ICT evolvement.

Future work is particularly needed on developing the new joint process and the required methods for the identification and inclusion of relevant stakeholders into the joint process at the right time instances. Those stakeholders may not be the existing dominant stakeholders of today, which makes the development of the joint process for digital transformation more complex towards realizing a sustainable future.

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