Paper I

Is the transport system becoming ubiquitous? Socio-technical road-mapping as a tool for integrating the development of transports policies and intelligent transport systems and services in Finland

Is the transport system becoming ubiquitous? Socio-technical roadmapping as a tool for integrating the development of transport policies and intelligent transport systems and services in Finland

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A R T I C L E   I N F O

A B S T R A C T

This paper examines the main development characteristics within the transport system as we are approaching the ubiquitous phase of the information society. Particularly the challenges in designing transport policies on a rapidly evolving technological frontier are emphasised. The theoretical background of the paper stems from policy assessment as well as futures studies, especially from technology roadmapping. The paper presents a socio-technical roadmapping method as a tool to integrate the technology developments better with societal developments and transport policy design. The method is tested with a Finnish case study, which provides three thematic, complementary roadmaps of the potential transport system technology services of the future. The roadmaps illustrate what kind of technologies, services, actors and related policy relevant knowledge is needed in satisfying the demands of transport policy development in the future's ubiquitous society. The case study reveals several changes in the transport system: pluralised number of actor roles and actor networks in the system, emergence of a new kind of business and service layer because of the new dynamic inter-linkages between the actors, and further, possibility to capture the service layer with the concept of "technology service". The changes require also re-conceptualisation of knowledge production to support transport policies. In conclusion, the socio-technical roadmapping holds great potentials as a tool for aligning technology development with transport policy development.

1. Introduction

In the field of transport, the concepts of planning and impact assessment, referring to infrastructural investments and project appraisals, have formed the frameworks and strategic lenses for transport policy development for decades [1–3]. However, due to the important role information and communication technologies (ICTs) have gained in our societies, the context of transport system and policy development has started to shift from designing road, railway or waterway lines or networks towards the development of a complex technological system largely depending on ICTs and applications (e.g. traveller information services,

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traffic management services, navigation, autonomous vehicle systems). Intelligent technologies and services are considered to have great potential, but on the other hand, e.g. due to reasons of privacy, security or public–private role divisions, they also pose great challenges to the transport system [4–7].

For example the Finnish Government [8] and the European Commission [4] see that Intelligent Transport System and Services (ITS), i.e. ICT applications for transport, also called transport telematics, hold a great potential in the future. According to these strategies [4,8], ITS will gradually provide new services for citizens and allow improved real time management of traffic movements and capacity use. New ICT-based systems are hoped to provide new benefits for transport operators and end users, and also endow public administration with rapid and detailed information on infrastructure and maintenance needs. In addition to the enhanced services for travelling and transportation needs, it is argued that ITS will also help in increasing transport safety and security and tackling with the wasteful transport patterns in the interest of environmental sustainability.

In this paper we trace the evolution of transport system in different phases of information society. Our view on the main transport related characteristics of these phases is presented in Section 2.1. These developments will have some impact on the ways in which people move and goods are delivered. As the environment and the needs and preferences of the transport system end users are changing, the knowledge production supporting system and policy developments should be responsive to these changes accordingly. We argue that conventional transport planning approaches, like cost-benefit analysis and impact assessments, are alone inadequate for addressing the systemic challenges of future transport systems. We further claim that mapping of emerging technological developments within a broader societal context is of crucial importance in the changing transport system.

Our perspective in this paper can be stated through following questions:

(1) What are the main development characteristics within the transport system as the society is moving, as we propose, towards the ubiquitous phase of information society?
(2) What kinds of tools and approaches are needed to integrate emerging technology developments with transport policies?
(3) What kind of tool is socio-technical roadmapping in this context?

The article is structured as follows: Firstly, we describe societal transformations on the way towards a ubiquitous transport policy environment as well as challenges in designing transport policies on a rapidly evolving technological frontier. Secondly, we present the theoretical background of our work, which stems from policy assessment as well as futures studies, especially from technology roadmapping.

In the subsequent results section we will show, based on our Finnish case study with three socio-technical roadmaps, what kind of technologies, services, actors and related policy relevant knowledge is needed in satisfying the demands of transport policy development in the ubiquitous information society. We conclude with a discussion on the both theoretical and practical implications of our method.

2. Towards a ubiquitous transport system

2.1. Transport system and the technological evolution of society

As many theorists have formulated, through different terms and varying concepts [e.g. [9–13], the societal development in advanced industrial countries has moved towards an information society, where the major driving forces are the development and rapidly increasing use of information and communication technologies (ICTs) and the growth of the knowledge-based service sector. ICTs and the related knowledge have been simultaneously rising in importance as production factors and as products [14]. In the information society, the ICTs are developing towards an infrastructure that will enable new kinds of practices also affecting the transport system, like teleworking and integration of ICTs in vehicles. Fig. 1 presents a generic societal framework for the emergence of technologies and services, which can also be applied for transport systems and policies.

The emerging phase of the information society can be called the ubiquitous information society. In the ubiquitous society of the future, we argue, the functioning of the transport system will increasingly be based on different mobile, flexible and personalized ICT services. The new technology brought into the transport system will change the nature of strategies and measures as well as the roles of the different actors within the system. In ubiquitous information society, ICTs will become a standard layer of infrastructure. This means that societal operations, such as mobility of people and transportation of goods, will widely be controlled and channelled through this infrastructure. Also the static components of the transport system, like roads, rails and bridges, will be monitored by ICTs. These static components communicate with mobile components of the system, like cars, trains and other vehicles, through sensors and other devices. Furthermore, the mobile components will constantly and automatically communicate with each other. The result will be a ubiquitous, networked transport system that can be characterized by an intensive layer of multi-directional and multi-actor communication. The fields of transport policy and management will expand from a macro-scale infrastructural level towards the micro-scale end-user level.

Table 1 reflects our view on the societal transformation from an agrarian to a ubiquitous mode. It also presents our vision on the role of transport in the ubiquitous society. The key idea in Table 1 is formed by the connections between socio-technical principles and logistic/transport principles that frame the views of the transport system and, thus, also the transport policy.

In the agrarian phase, the socio-technical principle was the combination of feudal communities utilizing local agricultural technologies. The utilization of and mobilization through natural channels such as rivers and the seas was the basic principle for transportation of goods and people. In the industrial phase, urbanization developed simultaneously with the emerging
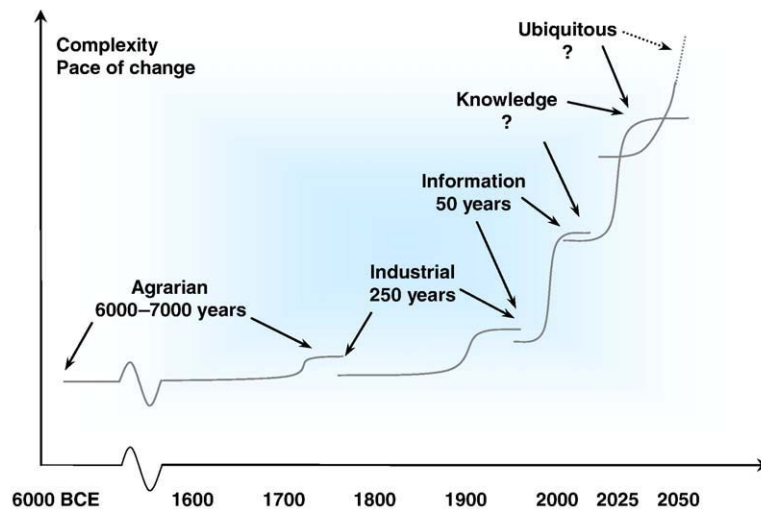
Fig. 1. Societal framework for the emergence of technologies and services.

technologies of mass production. This also led to a more systematic development of the basic transport infrastructure, e.g. roads, striving to fill the needs of the urbanized industrial nodes.

In the information society, the socio-technical principle highlights the information economy with its regional agglomerations and mega cities. The physical transportation principle is increasingly concentrated on the flow of bits in cables. However, the physical transportation principles of the earlier phases are also intensified. There are more traffic on the roads, more traffic on the rails and the seas. Furthermore, air transportation is steadily increasing as the transportation system becomes globalised and interconnected. The information society emphasises the combinations of electronic and physical transport as its logistic principle.

The following phase, the knowledge society, is actually a deepened and intensified version of the information society. In this phase, the information technology becomes the key enabling technology of the transport system. It functions as the basic tool in controlling the system and also as the key infrastructure. The transport system is more and more governed by ICT-based management solutions. To support the development and functioning of the system, new forms of knowledge production are also needed.

In the ubiquitous phase, transparency becomes the key socio-technical principle in the society. Transport system is a global system, a grid that functions and constantly communicates at every level—man-to-man, man-to-machine and machine-to-machine. During this phase, the transportation principles change and we can start to speak of a new, transparent operation mode that combines technologies and services.

It is through this societal frame, highlighting the transparent and ubiquitous functioning of technologies, that we discuss the notion of technology services and the related assessment knowledge in this paper. We define technology services as the combinations of technologies and services that are enabled by interlinking the static transport system and the information infrastructures, gathering, processing and delivering information, and its mobile actors, e.g. people, goods and vehicles. We propose that technology services are the products of a society utilizing ICT as its basic infrastructure and service platform. Technology services are also products of transparency: the services are based on the continuous communication between actors in the transport system and they can be tailored for different kinds of purposes.

Our definition of technology services come quite close to the concept of "innovative product-related services" proposed by Lenfle and Midler [15]. Their starting point is the every-day confusion with concepts of product and service that are sometimes interlinked and might have quite osmotic boundaries. Lenfle and Midler [15] argue that the introduction of service component

Table 1
Societal framework for the emergence of technology services.

Societal phase	Socio-technical principles	Logistic/transport principle(s)
Agrarian	Feudal communities; local agricultural technologies	Utilization of natural channels
Industrial	Urbanization; technologies of mass production	Development of basic transport infrastructure
Information (physical infrastructures)	Information economy, regional agglomerations; megacities; Information technology	Combinations of electronic and physical transport
Knowledge (economic sphere)	Global information economy, regional agglomerations, megacities; Information technology as enabling tool and infrastructure in itself	ICT-based management of transport and logistic services
Ubiquitous (realtime and transparent information/knowledge)	Global system (grid), regional polarization; ubiquitous technologies	Ubiquitous, transparent and tailored technology services

"does not mean that physical goods disappear from our universe but that they are more and more associated with complex services". The idea is that technological devices and systems are increasingly utilized as parts of advanced service concepts formed by companies and public organizations, sometimes even by private persons. In the next two sections, we turn to challenges of transport planning that tries to cope with the changes described above.

2.2. Transport planning — the traditional approach for transport system and policy developments

The rational transport planning approach as a knowledge production practice for transport domain evolved in early 1960s, and with minor variations has ever since served as the main methodology for transport planning. The rational transport planning process begins with an articulation of policy or community goals, leading to an identification of transport system problems. Once these problems are identified, alternative solutions are identified and assessed, and a set of actions recommended based on which alternatives return the most benefit for the costs incurred [1,2,16].

Within the traditional transport policy and project planning approaches, there exists a wide range of different assessment methods or tools for data collection, analysis as well as for formal assessments. As regards formal assessment techniques, cost-benefit analysis (CBA) is very well established in transport as a means of aggregating the impacts of competing transport (infrastructure) proposals so as to get an overall ranking in terms of contribution to social well-being. Generally CBA is used when the objective of evaluation is to compare the costs and benefits of a project using a common denominator (usually money) in order to decide on whether costs outweigh benefits or vice-versa [e.g. [17–21]].

Multi-criteria analysis (MCA) is often presented as an alternative to CBA in cases where the majority of important effects cannot be monetised or CBA is not seen sufficient to ensure the multi faceted understanding of a plan or policy that is increasingly required [22]. In addition, Environmental Impact Assessment (EIA), Social Impact Assessment (SIA), Strategic Environmental Assessment (SEA) and Socio-Economic Cost-Benefit Analysis (SCBA) have been commonly used in transport project assessments. Mostly due to the ITS development, the interest to and use of Human–Machine Interface (HMI) design, user requirements and specific field tests has increased to supplement the traditional approaches.

The existing frameworks have typically been used for infrastructure assessments at a project level, for ex ante assessments (i.e. appraisals), and for prioritizing purposes. They have focused primarily on economic efficiency. Distributional questions have only been considered to a limited extent. Assessments have mostly been inter-urban and only rarely responsive to interactions outside the transport sector. Hence the assessments have not been consciously oriented towards wider societal concerns [e.g. [1,2,20] and [21]]. Further, the role of citizens in transport policy design has so far been rather limited. This is because citizens have not been seen as contributors to policy making, but rather as objects of policy — in addition to having the role as consumers and users of end products. However, the shift toward market governance in ICT policies, and consequently in ITS developments, has resulted in the increasing interest in consumer needs and preferences as a basis for transport technology design, e.g. in the studies of human–technology interfaces and design.

In the ubiquitous transport system, which we presented in Section 2.1, the traditional rational planning paradigm is no longer sufficient in providing the knowledge needed to understand the socio-technical nature of the transport system and the dynamics between the different actors. For example, the roles and the networks of actors in transport system will be pluralised. Transport system will be more and more composed of complex networks that consist of public parties, private parties and contributing end-users. We suggest that in the future, most of the actors within the transport system will equally use and produce knowledge via ICT devices as the basis of their actions. This requires re-thinking also of the knowledge production for transport policies and decision making.

New kinds of systemic knowledge structures are thus emerging in the transport system. Tuomi [23], for example, has defined three research domains of knowledge society that are interlinked in the ongoing societal transformation. These domains are: institutions & culture, everyday life, and systems of production. The transport system lies in the intersection of these domains, which naturally puts pressure on the transport sector to stay as sensitive to changes in society as the other domains. This requires wider, multidisciplinary approaches to be introduced also into the transport policy making process (e.g. [1,3,20], and [24]).

The Science and Technology Policy Council of Finland [25], based on Valovirta and Hjelt [26], presents another view for identifying policy-relevant information for strategic decision making in the future. The monitoring of the socio-economic development (i.e. how economy, society and technology have changed) and the evaluation of policy actions form the policy-relevant information about the past. Expected future socio-economic developments mapped with different kinds of foresight exercises (e.g. roadmaps, mega trends, and weak signals), *ex ante* impact and technology assessments as well as policy analysis regarding the policy options available and their expected impacts, provide tools for producing policy relevant future information.

2.3. Challenges in designing transport policies for a ubiquitous society

Some theorists of ICT-related social change [e.g. [27,28] see that there is a possibility that we are on the cusp of a major social and economic transition. One dimension of this transition is that policy makers and other societal actors throughout the world need to understand the systemic nature of changes occurring in society. These changes are not necessarily visible through official statistics. Also commercial actors will need to understand the same processes. This approach lends itself well for the transport sector, too [e.g. [27,29,30]].

The growing emphasis on new technology industries and services and the consequent market governance will also change the concepts of knowledge production and competencies. As the policy environment for transport design and the needs and

preferences of the transport system users' are changing, the assessment and analysis practices concerning the transportation system should also reflect on these changes. The conventional assessment methods, like cost-benefit analyses and impact assessments, are not adequate for addressing contemporary systemic challenges of transport policies. Consequently, the needs for transport assessments are evolving from project assessments to broader analyses of transport system in its societal context.

There are, however, great challenges related to these kinds of systemic socio-technical perspectives in transport planning. Geels and Smith [31], for example, have identified seven key pitfalls in exploring the future technological developments in transport. In one way or another, all of these pitfalls relate to the socially constructed nature of transport system. The authors argue that the images of the future are often based on too simplistic conceptualisations of technological development and its impact on society, ignoring especially the dynamic co-evolution of technology and society. The concept of technological frames, introduced by Olikowski and Gash [32], emphasises the same issue. Technological frames build on a wide range of previous studies about the perceptions and values of designers and users (the social aspects) in constructing information technologies. Olikowski and Gash [32] argue that an understanding of peoples' interpretations of a technology is critical when trying to understand their interaction with it. Currently, the pace of development as regard to transport technologies is quite different from that of the technological frames for transport systems, which poses problems, especially in acceptance and use of new transport technologies.

As Rycroft [33] and Rejenski [34] highlight, current policy practices are not capable of dealing with fast-paced technological innovations. According to Rejenski [34], main characteristics of new, complex technologies, like adaptation, co-evolution and agility, are difficult concepts to be grasped by current public policy agendas. Rejenski argues that new technological environment requires us to rethink the linkages between the temporal dimension of technological innovation and public policy. The policy formulation should be re-invented and made more sensitive to complex technological issues. Things are made even more complex by the idea of technology services, i.e. combinations of technologies and service concepts.

van Zuylen and Weber [35] argue, technological transport innovations are only beneficial if they are integrated into services or transport concepts. This development towards technology-based services calls for organizational changes, because in new environment the role of governments will potentially also change.

3. The method and the Finnish case study

3.1. The setting

Finland is often seen as one paradigmatic information society due to the fast rise of the Finnish ICT sector during the 1990s [36]. Generally speaking, public policies on ICT in Finland have been based on two main foundations: the selective technology policy where ICT, together with biotechnology, have been the key targets of public funding, and the liberalisation and market orientation of telecommunications [37,38]. In the vision of the Finnish information society, the role of information technology and data networks is to bring forth efficiency, organizational renewal and new forms of collaboration as well as promote the network economy by opening up the development of new services and industries [39].

It is not commonly acknowledged that a transport system is not just about physical networks. A transport system – be it international, national or local – is a large technological system, which contains messy and complex components. It is a socio-technical network. The state of the transport system results from the measures and actions carried out by the producers, operators and users of the system, who affect and shape the system by their behaviour and actions. The system is thus both socially constructed and society shaping [40].

In our case study we dealt with the above mentioned issue of societal context by carrying out a socio-technical roadmapping process that included different actors and perspectives, e.g. decision makers, technology developers and end users, to support both ITS and transport policy developments in Finland. Following the interpretation of Ragin and Becker [41] to see cases as theoretical constructs ("cases are conventions") we consider Finland's ITS development as an appropriate case for our study.

3.2. Socio-technical roadmapping as a case study method

Roadmapping is a methodology that has been applied in several industrial organizations in order to facilitate and communicate technology strategy and planning. Roadmapping approach provides a structured and often graphical means for exploring and communicating the relationships between evolving markets, products and technologies over time. Roadmaps can take a variety of specific forms depending on the roadmap type, e.g. technologies, products, capabilities and resources, and on the particular organizational context.

Basically, roadmaps aim to provide an extended view on the future of a chosen field of inquiry, as the now classical formulation states [see [42]]. They also make inventories of different possibilities, communicate visions, stimulate investigations and monitor progress. In other words, roadmaps are composed of the collective knowledge and the imagination drivers of change in a particular field [e.g. [42–45]. According to a classic text by Kostoff and Schaller [42], roadmaps can be categorized broadly into four categories: 1) S&T roadmaps, 2) industry technology roadmaps, 3) corporate or product-technology roadmaps, and 4) product/portfolio management roadmaps. New approach to roadmapping is to use them to map potential technology disruptions [46]. Particularly useful crystallizations of the roadmaps is to approach them as strategic lenses [47], or more widely, as strategy roadmaps that visualize and describe the core issues of a strategy e.g. for an organization [48].

In the fields of transport infrastructures, mobility and transportation of goods, vehicles and transport policies, foresight and assessment approaches have been utilized for a wide range of topics already for quite sometime. Methodologically, the foresights and assessments have applied different variations of Delphi [49], cross-impact analyses [49], scenarios [50] or combination of both [51]. Also, a new kind of integrative foresight approaches have been applied in the field of transport. One interesting example is adaptive foresight [52] that combines foresight approach with adaptive strategic planning and innovation process approaches. Furthermore, the targets of the analyses have accentuated e.g. European level strategic innovation policy approaches [35] and technological alternatives to advance sustainability in transportation system at national levels [53]. One important emerging topic has been the overall energy efficiency of transportation system and utilization of alternative technologies that could ease our dependency on fossil fuels. In this field, foresight studies have touched upon topics such as trends in energy usage and emissions passenger vehicles [54], development of alternative technology paths for transport fuels [55] and new kind of energy distribution technologies, like vehicle-to-grid systems [56]. Also, overall sustainability of transport and life cycle issues have been important new topics [e.g. [57]].

Roadmapping is still a relatively new foresight method in the field of transport and transport infrastructure. However, some examples can be found in the areas of transport technologies [e.g. [58–60]], energy [e.g. [61,62]] and from related infrastructures, such as waste management [e.g. [63]] and water coordination [e.g. [64]]. Roadmaps have also been constructed on topics such as the future of cars and vehicles [e.g. [65,66]]. Fuel and energy systems for cars and transportation in general have been central emerging topic in the foresight and assessment studies [e.g. [67]].

The aims of the above-mentioned roadmaps are more or less technological, i.e. they primarily seek to identify crucial technological developments that could be realized by setting technological targets and forming action recommendations. In our case study, we have applied roadmapping method to study the emergence of a new kind of ICT based knowledge and service layer on top of traditional transportation infrastructure. We call the layer "technology services". We put emphasis on technologies in specific contexts, i.e. we have tried to identify meaningful technological developments and their connections to the evolving networks of actors. In this sense, our approach comes quite close to strategy roadmapping described above [48]. Furthermore, we have also mapped the changing forms of information needed to grasp these developing technologies and actor contexts. Therefore, we utilize a special brand of roadmapping—labelled visionary socio-technical roadmaps—to study the changing transport system and related policy design [68].

Visionary socio-technical roadmaps aim for the basic roadmapping objectives defined above, by (1) emphasising the application visions that are embedded in the roadmap structure and (2) by combining different layers of society and technology. Our transport system roadmaps consist of five layers: user needs, markets, actors, technologies and assessment knowledge. It is crucial to note that the roadmaps are application-oriented and visionary, i.e. they do not try to depict all the possible development trajectories relevant to the sector under scrutiny. Instead, the roadmaps produce partial glimpses of the elements and development paths surrounding a certain application. Roadmaps have typically been described as links between concepts such as product, technology and science. However, in a wider societal framework or in the field of knowledge production for policy processes, which is our main field of interest, the roadmapping method has not been commonly applied, even though a demand for it seems to exist [e.g. [68–70]].

In the following, we present the results of a socio-technical roadmapping process completed in Finnish context. We claim that this approach and other related approaches are important tools to gain better understanding of the socio-technical and systemic nature of the transport system among both policy designers and technology developers, and furthermore to encourage the use of a systems perspective as a basis for transport policy development.

3.3. Characterization of the case study

Our case study, named "Research directions for future transport service assessments" [29], was targeted towards the following vision: "The Finnish transport system and its technology services are developed on the basis of the best possible knowledge about the impacts of the development measures on the effectiveness and functionality of the system, the activities of different transport system users as well as on the environment." In this study, we produced visionary socio-technical roadmaps of the potential future trajectories in Finnish transport system. Roadmaps included examples of technology services and evaluations of related
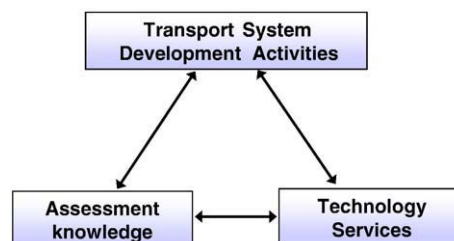

Fig. 2. Three knowledge elements of the case study.

Fig. 3. Roadmapping process.

assessment knowledge needed in their development. The timeframe of the study was to the year 2025. Fig. 2 presents the basic knowledge elements of the roadmaps: transport system development activities, technology services within these activities and related assessment knowledge.

The actual roadmapping process comprised of three phases: (1) background study, (2) workshops and their intermediate phase, and (3) reporting and presentation of final results (Fig. 3).

The first phase started with definition of objectives, vision and corresponding research questions. In order to validate the chosen objectives and the vision, the phase continued with the collection and analysis of relevant publicly available material. The material comprised mainly of policies, strategies, foresight and research reports in the field of transport, or in closely related fields, such as land use or safety and security at the Finnish national and European levels.

The second phase consisted of two workshops and an intermediate desktop study phase. In the first workshop, the participants were divided into three thematic groups, namely: (1) transport infrastructure; (2) transport services; and (3) transport policy design and implementation. Each of the groups provided two outputs: (a) a thematic mind map, and (b) prioritization of elements in the mind map that were chosen for the further elaboration. In our study, mind maps applied the basic ideas of futures wheel (for more information see: [71]) in the following way: The theme of the group constituted a core element of the mind map. The task of the groups was to construct three circled topic areas representing (1) the future challenges for transport system development; (2) the transport technologies or services answering those challenges; and (3) the assessment knowledge relating to the technologies or services (Fig. 4).

Each group identified elements that in the future could affect the transport system and produced a description of their linkages with other elements. The elements were then prioritized by giving votes to second and third level elements. Top three elements were chosen for further elaboration. Between the two workshops, the results of the first workshop were analysed and constructed into roadmap templates. Roadmap templates had the following generic structure: user needs, markets, actors, enabling technologies, and assessment knowledge (Fig. 5). Second workshop focused on the elaboration of roadmap templates, especially on enabling technologies and assessment knowledge. Also, in the second workshop the participants produced visionary application examples that could enable the realization of the vision.

The third phase of the roadmapping process comprised of finalising the three roadmaps and reporting the process. It is important to note that the roadmaps were compiled to reflect the themes found particularly important by the workshop
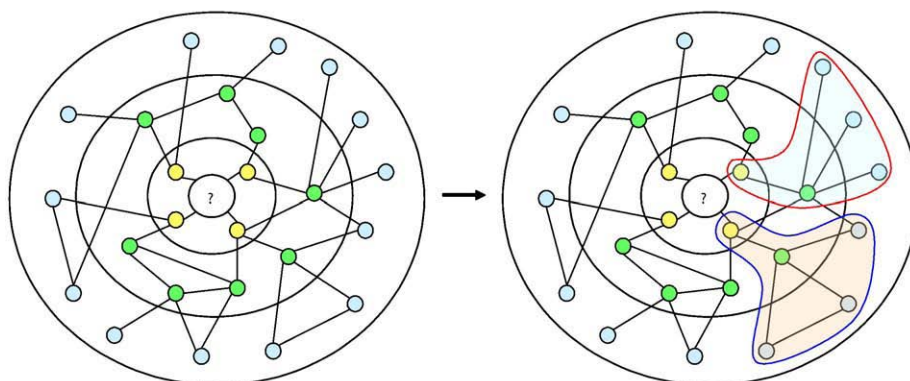

Fig. 4. Example of thematic mind map and presentation of technology/service elements and their linkages.
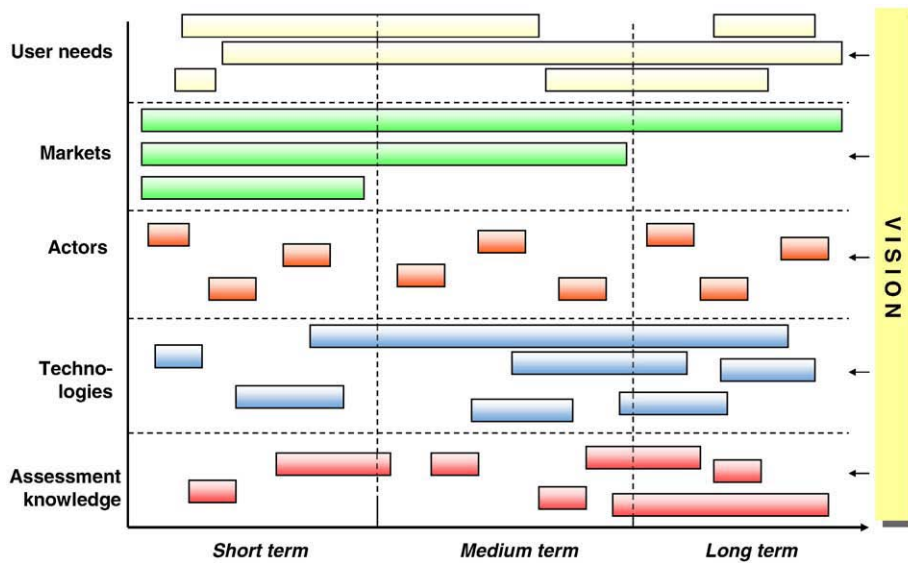
Fig. 5. Generic roadmap structure.

participants from the Ministry of Transport and Communications Finland, the Finnish Road Administration, the Finnish Motor Insurers' Centre, the Confederation of Finnish Industries and VTT Technical Research Centre of Finland.

4. Roadmaps of technology services in the changing transport system

The roadmapping process indicated that in the ubiquitous society of the future, a concept here called "technology service" could become an important idea for understanding the dynamics of technologies, applications and actors in transport system. In the roadmapping process we defined technology service as a flexible and tailored combination of technologies and services which takes into consideration the travel or transportation preferences, needs and expectations of the different transport system end-users (see also Section 2.1). The emergence of tailored technology services brings new challenges to decision makers, private actors, and other societal actors. Consequently, the roles of public and private parties in the transport system will intermingle in different ways, and new business models and operational practices will arise. In the following, we present the results of our exercise in the form of three roadmaps (Fig. 6).

The thematic roadmaps provide three different, but complementary, perspectives into the development of transport system technology services. We consider each perspective as equally important in the creation of well balanced technology services that are accepted and utilized by actors in transport system. Networking technologies create the settings for general service development. Real time information based interactive systems offer information in a custom-built format for the end-users. Service packaging helps in implementing user friendly technology services (Figs. 7–9).

4.1. Roadmap 1: networking technologies

The first roadmap, Networking technologies, presents applications and co-operation concepts that could make assessment knowledge accessible to different actors in the transport system. The vision for the roadmap is: "The information flow between public and private producers and end-users, e.g. companies, citizens, regarding transport system design, assessment as well as
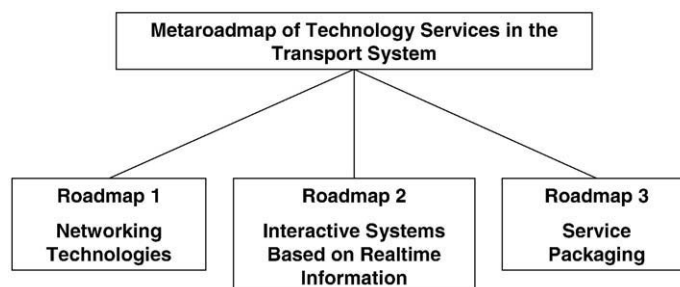
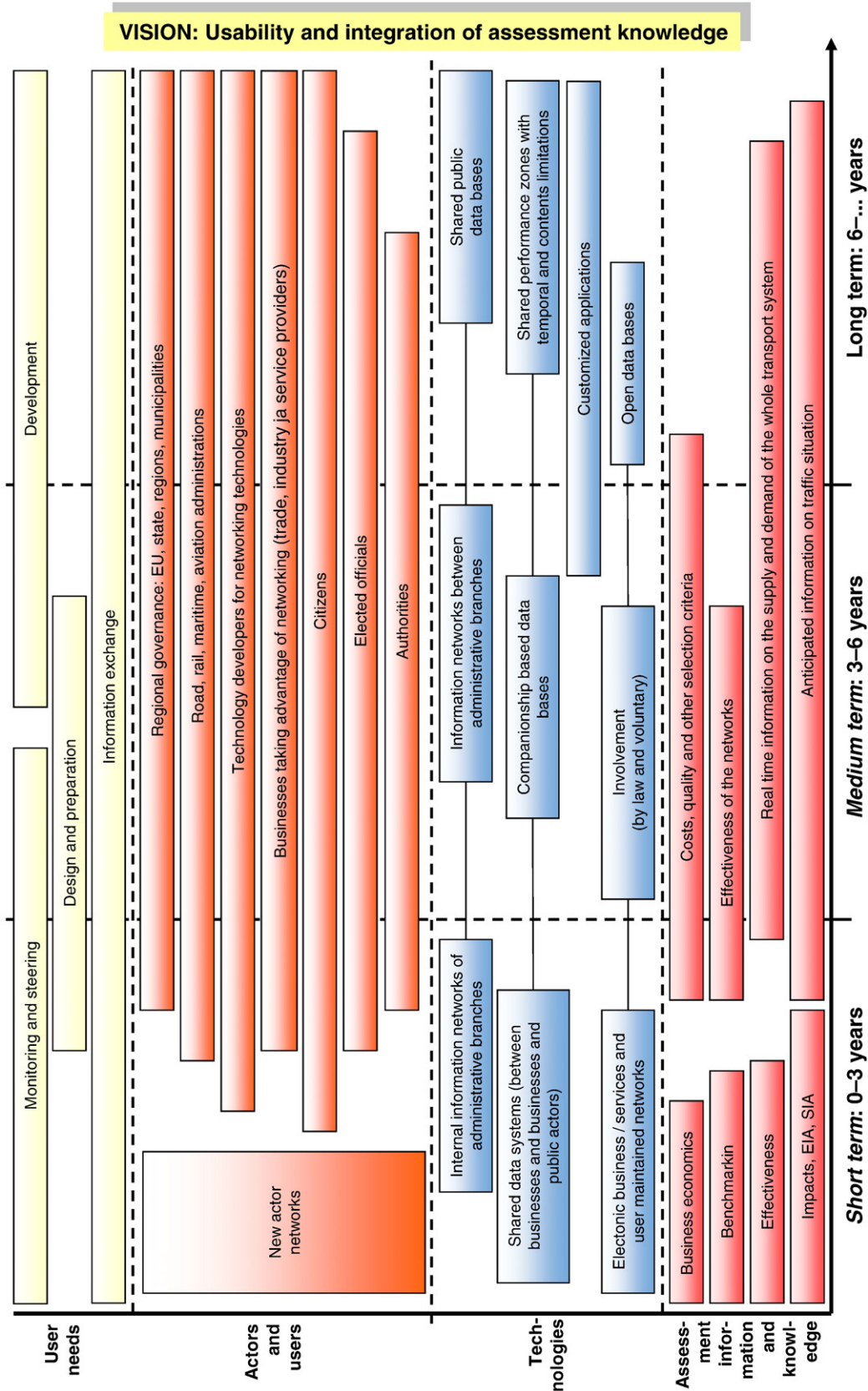

Fig. 6. The four roadmaps produced.

VISION: Usability and integration of assessment knowledge

	Short term: 0–3 years	Medium term: 3–6 years	Long term: 6–... years

User needs
- Monitoring and steering
- Design and preparation
- Information exchange
- Development

Actors and users
- New actor networks
- Regional governance: EU, state, regions, municipalities
- Road, rail, maritime, aviation administrations
- Technology developers for networking technologies
- Businesses taking advantage of networking (trade, industry ja service providers)
- Citizens
- Elected officials
- Authorities

Technologies
- Internal information networks of administrative branches
- Information networks between administrative branches
- Shared public data bases
- Shared data systems (between businesses and businesses and public actors)
- Companionship based data bases
- Shared performance zones with temporal and contents limitations
- Electonic business / services and user maintained networks
- Involvement (by law and voluntary)
- Customized applications
- Open data bases

Assessment information and knowledge
- Business economics
- Costs, quality and other selection criteria
- Benchmarkin
- Effectiveness of the networks
- Effectiveness
- Real time information on the supply and demand of the whole transport system
- Impacts, EIA, SIA
- Anticipated information on traffic situation

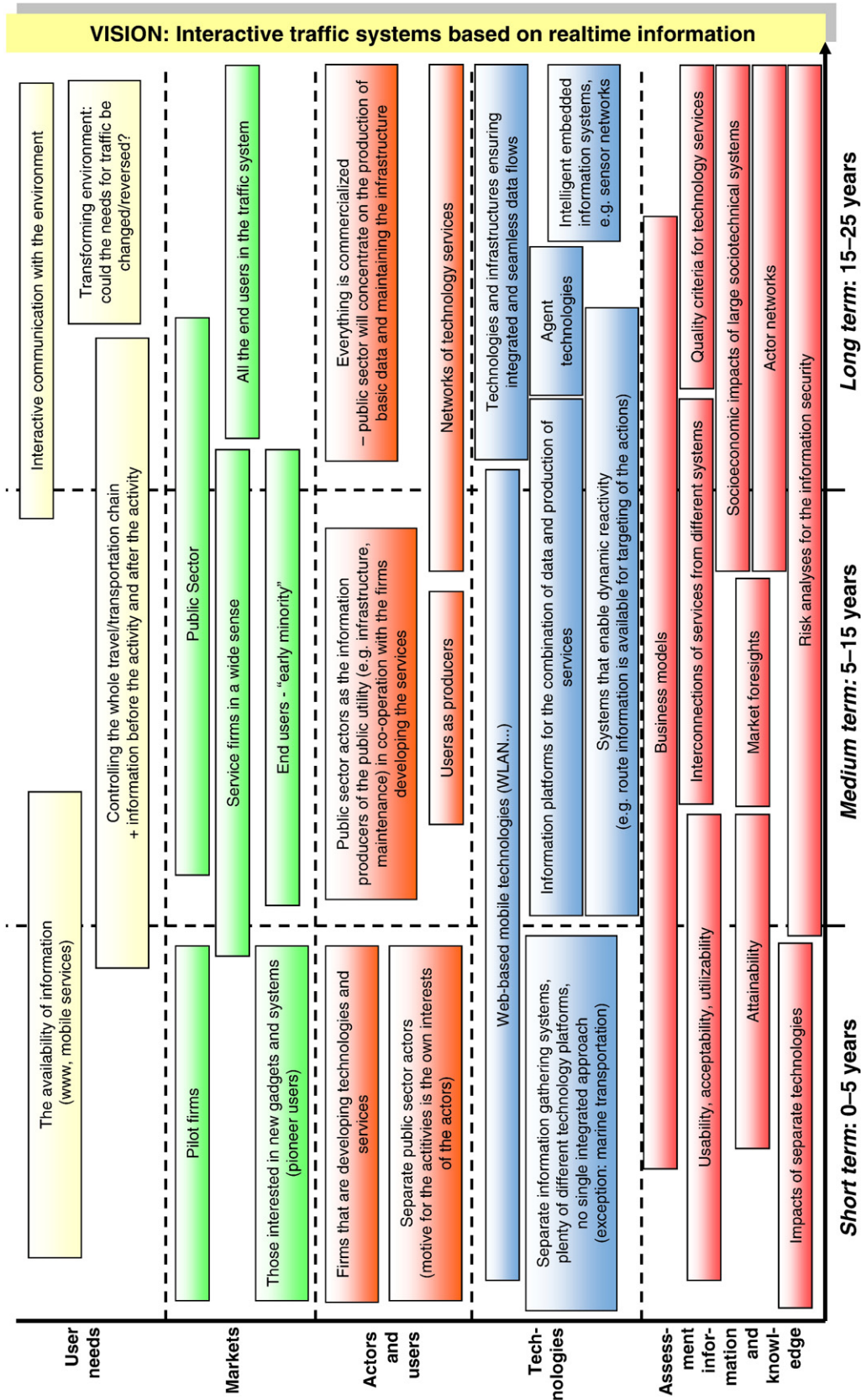**Fig. 7.** Roadmap 1: networking technologies.

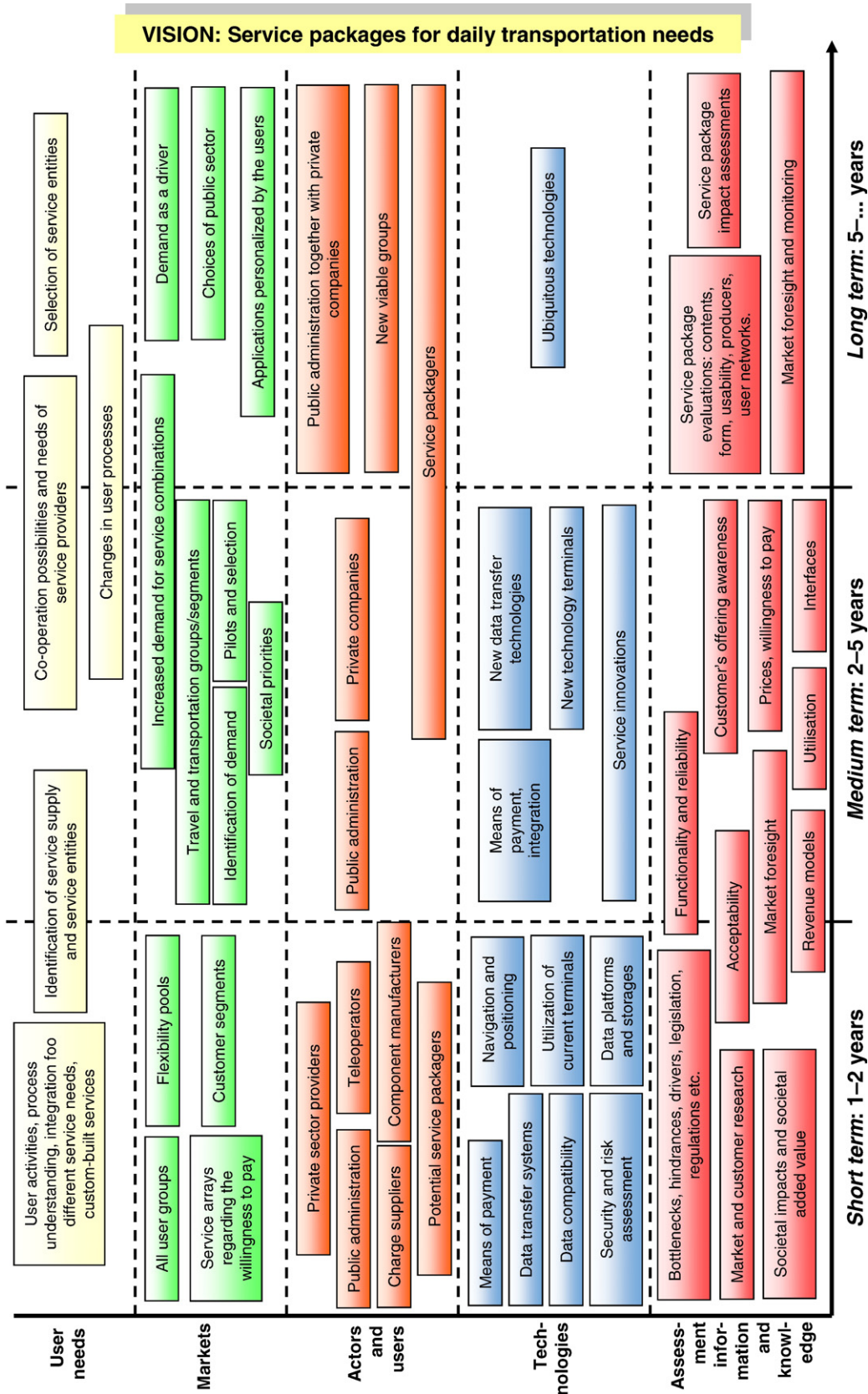**Fig. 8.** Roadmap 2: interactive systems based on real-time information.

Fig. 9. Roadmap 3: service packaging.

implementation, is systematically organized. New knowledge relevant for transport policy is produced within commonly constructed and accepted policy networks."

4.1.1. Roadmap description

In the short term (0–3 years), the user needs will focus on information exchange relating to transport system monitoring and control. The main emphasis will be on the fields of easy access to and comparability of the produced information, as well as finding descriptive indicators for the system development. The technological base for the networking technologies stems from ICTs, combining e.g. information exchange optimisation, mobile social media and geographical information systems (GIS). In the public sector, networking in the short term is limited to internal information systems in different administrative bodies and institutions. Impact assessment based on cost-efficiency is the primary mode of required assessment knowledge.

In the medium term (3–6 years), internal information networks of the public administration sectors will emerge. Even inter-sectoral networks may become possible, allowing the utilization of information from other sectors as a basis for transport system design. On the private sector, the emerging partnership networks will serve the needs for information/knowledge of both passenger and freight transport. These networks could also integrate public and private actors e.g. in infrastructure design, construction and monitoring. Public participation in the design of transport systems will increase due to electronic communication. As a result, the role of transport system user networks as critical system designers is enhanced in the medium term. The assessment knowledge needs in medium term will focus on quality, costs and some specific selection criteria for networking technologies. Also, real-time transport information, forecasts based on real-time information, as well as assessments of the transport system demand and supply will be of high importance.

In the long term (6– … years), the transport system development objectives will focus on utilization of open information and databases. Integrated databases will alleviate the use of assessment and monitoring information in transport system research, design, citizen participation and implementation. There will be two different types of information within the transport system management: 1) freely available public information critical for transport system functionality and safety; and 2) "non-free" information with commercial value. The line of demarcation between publicly available and commercial information will not be easy to draw, because commercial information may be produced also by tailoring, packaging, revising and personifying publicly available information.

4.2. Roadmap 2: interactive systems based on real-time information

The second roadmap, Interactive systems based on real-time information, presents technological complexes that give transport system end-users a constant access – through vehicles or mobile devices – to real-time information on travelling/transport possibilities in the system. The vision of the second roadmap states: "Interactive, mobile information systems will support travelling and the transportation of goods before, in the course of and after the journey. Infrastructure, vehicles, and transport service providers will exchange information, which will enhance the fluency, safety, and eco-efficiency of the transport system."

4.2.1. Roadmap description

In the short term (0–5 years), the needs of the transport system user will focus on easy access to travel and transport information concerning different transport modes. Mobile interfaces will be the primary channel in information distribution. The potential market segments for the new applications will include pioneer companies in need of real-time logistic information and technology oriented individuals, early adopters. Information systems will be provided by different private service providers and public sector branches. Enabling technologies will consist of many separate, i.e. mode-specific, data gathering systems. No common platform for the production, processing or use of information will be available in short term. The assessment knowledge needed in developing the above mentioned services relate to the analysis of individual data systems from the perspectives of e.g. interface design, implementation, acceptance and security. Foresight knowledge regarding business model development and market developments will also be essential.

In the medium term (5–15 years), the integration of different information modes in the transport system will increase, targeting towards one systemic network. Users of the system will be able to plan their trips in advance and use saved information during the journey in an interactive manner. Different sensors within the infrastructure and the vehicles will continuously gather transport information for the use of both public and private sector actors. The main challenge will be finding an appropriate provider for the whole information system. The service providers will combine transport information from different sources into new services, which will be used by even wider pool of end-users. The needed assessment knowledge to realize this will include business model development, analysis and market foresight for system wide services, provided in collaboration with private and public parties. In addition, assessments regarding the utilization of older and smaller systems as parts of the new integrated system are of pivotal importance.

In the long term (15–25 years), transport services are based on interactive real-time information systems. Service environment will develop towards end-user oriented consumer markets. Mobile ICTs will enable the communication and information flow between vehicles and infrastructures, but on the other hand, it will require development of a common data/knowledge platform for different service providers. Many different sources, e.g. individual persons and vehicles, will be used to gather critical information regarding the state of the transport system. Technology producers and service providers will operate in the service networks striving for increased service efficiency and quality. Public sector will have an important role as network builder and provider of basic knowledge.

4.3. Roadmap 3: service packaging

The third roadmap, Service packaging, answers to the daily transportation needs of individual people and firms. Service packaging helps transport system users to create a selection of individual technology services assisting in travelling or transportation. However, service packaging is also important e.g. in business where logistics are crucial part in the overall service. According to the roadmap vision: "Service packaging enables the customers to define their individual selection of transport technology services. Service packages are easy to acquire and use and their costs are on a reasonable level."

4.3.1. Roadmap description

In the short term (0–2 years), the focus will be on understanding the current actions, processes and preferences of the end-users. Markets for service packages will be formed among all user groups both in passenger and goods transport. Service packages may assist in managing the large logistic processes of large companies as well as the small tasks in people's everyday lives. Here, finding the right target groups for the packages as well as their accurate pricing is essential. Also the development of commonly accepted terminal devices and payment systems will be important. Databanks, data transmission and processing systems will constitute the foundations of the services. Data security, data consistency and risk management will be the main challenges for service packaging in the short term. The most important assessment knowledge needs include market and customer studies, societal impact assessments of the service packages and identification of the legal bottlenecks for new service packages.

In the medium term (2–5 years), more wide ranging service concepts will emerge. The co-operation possibilities, needs and preferences of different service providers as well as the roles of public and private parties within the service packaging will become clearer. Technological development will focus on further development of data transmission, payment systems and terminal devices. The assessment knowledge needs include assessments of the functionality and reliability of service packages, service package interface design and market foresight for new services.

In the long term (5–… years), service packages that have the highest response among the transport system end-users will survive. Public sector may be able to steer the development with its own choices e.g. by subsidies. New, viable clusters of service providers will dominate the markets and ubiquitous technologies will form the basis of technological development. Also, user-driven transport-related social media services are in use. Market foresight concerning the new service packages will, furthermore, be one of the key forms of assessment knowledge. Assessments regarding the functionality and impacts of wide service areas will also be important from the viewpoint of business development.

5. Discussion

Based on our case study, we argue that societal development leads to at least three kinds of changes in the future transport system. Firstly, the actor roles and the actor networks in the system will be pluralised. The transport system will increasingly be composed of public parties, private parties, contributing end-users and complex networks formed of these actors. Secondly, a new kind of business and service layer will be formed in the system because of new dynamic inter-linkages between the actors. This emerging service layer will give possibilities to new kinds of public–private relationships and end-user perspectives. Thirdly, we propose that this service layer could be captured with the concept of "technology service". In the paper we defined technology service as flexible and tailored combination of technologies and services that takes into consideration the travel or transportation preferences, needs and expectations of the different end-users in the transport system.

Our roadmapping process revealed that – to be able to develop working and practical technology services in the future and integrate the developments with policy developments – there are at least three complementary perspectives to consider. These perspectives were the themes of our roadmaps, namely networking technologies, interactive systems based on real time information and service packaging. Examples of approaches needed to integrate the technology developments into transport policy developments are societal impact assessments, user-centred design and different future oriented assessments regarding e.g. service demand, emerging market needs and new business models.

Based on our case study, we argue that in the short and medium term (1–10 years), the approaches supporting transport system technology services should emphasise following topics: market foresight, technology assessment, business model assessment and evaluation of integrated data systems, societal impacts and effectiveness of the technology services in public–private production environment. From end-users' point of view, essential assessment knowledge relates to the users' activities and acceptance of new devices and applications, as well as to the co-operative interface design. In addition, it is important to identify legal and organizational obstacles relating to new technology services. In the long term (10–25 years), the needed approaches in the transport system emphasise interfacing possibilities, joint implementation of different interactive systems, security and privacy, business models, criteria for data transmission and societal impacts.

The case study summarised above supports our argument that moving up the ladder of information society, towards ubiquitous knowledge society, poses unique challenges to the development of transport systems and transport policies. In order to grasp the networks dynamism in the system, a rethinking and reconceptualisation of knowledge needs is required. To cope with this increasing systemic complexity, traditional transport planning approaches should be complemented with societal and actor-oriented, proactive approaches. We claim that foresight methods, like visionary socio-technical roadmapping, can provide good premises for the implementation of this wider societal perspective.

To conclude, the socio-technical roadmapping method tested with a Finnish case study proved to be useful in producing transport policy relevant knowledge from at least five different perspectives (roadmap levels). It also provided an interactive foresight platform that brought researchers and policy actors together and stimulated future oriented discussion on transport visions, policies, technologies, services and their interdependencies in a collaborative manner. We find that method holds potentials not just as tool of technology foresight, but also as a tool for new agenda identification and network building in complex societal-technological systems, like transport system is.

Acknowledgements

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