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Knowledge production for transport policies in the information society

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Keywords transport policy, knowledge production, information society, transport system

Abstract

This dissertation explores and analyses the challenges and needs that developments in the information society are bringing to knowledge production supporting policy development and strategic decision making in the field of transport. Currently, the context of transport policies is about to shift from a transport infrastructure network design towards the development of a large socio-technical system, depending largely on ICT technology and applications. Dynamic decision making clusters or networks, consisting of different actors and having a variety of goals, are growing around policy items or transport system innovations, and they need information and knowledge as the basis for their mutual decisions. This development will change the roles of the different actors within the system as well as the nature of strategies and measures.

My key argument is that in this new context the traditional, analytical knowledge production approaches (such as “planning” and ”impact assessment”, referring to infrastructure investments and project appraisals) are alone not sufficient in providing the knowledge needed to understand the socio-technical nature of the transport system or the dynamics between the different actors, as a basis for transport policy development. The knowledge provided to make informed transport decisions needs to include, in addition to the traditional issues, also new forms to serve the needs of a wider variety of societal actors. Based on the field of science and technology studies (STS), which aims to illuminate the relationship between knowledge and political power as well as investigating the place of science and technology in society, I have identified five emerging forms that I consider relevant to transport policy knowledge production in the future. These are knowledge production through system-based foresight, knowledge production through system-based evaluation, knowledge production in networks, knowledge production as processes of social learning and argumentation, and knowledge production as a source of renewal. Further, I have identified the basic characteristics of these forms. I believe that the presented forms can shed light

on the relationships between knowledge production, policy making and the society, which may lead to the implementation of new, socially embedded ways of developing transport systems and policies. The dissertation also presents implications of these emerging knowledge production forms for transport policy and business development (in Finland) and related future research needs. The thesis is an article dissertation including four scientific papers (Papers I–IV) and this summary chapter, bringing together and elaborating further on the ideas of the individual papers.

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Avainsanat transport policy, knowledge production, information society, transport system

Tiivistelmä

Väitöskirja tarkastelee tietoyhteiskuntakehityksen mukanaan tuomia muutostarpeita, jotka koskevat liikennepolitiikkaa, liikennejärjestelmien kehittämistä ja näihin liittyvää strategista päätöksentekoa palvelevaa tiedontuotantoa. Liikennejärjestelmä on murroksessa – se on muuttumassa vähitellen kohti kommunikoivaa systeemiä. Kommunikaatiota ja tiedonsiirtoa tulee tapahtumaan liikennejärjestelmän eri osien, käyttäjien (ihmisten ja yritysten), kulkuneuvojen ja infrastruktuurin, välillä kaikkiin suuntiin. Myös julkisten ja yksityisten toimijoiden roolit liikennejärjestelmän kehittämisessä muuttuvat ja sekoittuvat. Liikennepolitiikan valmistelun ja strategisen päätöksenteon apuvälineiksi tarvitaan perinteisten vaikutusarviointien lisäksi uudenlaisia toimintamalleja ja käytännön työkaluja, jotka pystyvät ottamaan huomioon entistä paremmin liikennejärjestelmän sosioteknisen luonteen ja muuttuneen toimijakentän.

Väitöskirjan teoreettinen viitekehys koostuu pääosin tieteen ja teknologian tutkimuksen esille nostamista uusista tiedontuotannon käytännöistä ja teorioista, jotka pyrkivät ilmentämään tieteen, teknologian ja poliittisen vallan välisiä suhteita yhteiskunnallisessa päätöksenteossa. Työssä sivutaan myös perinteisiä liikenteen vaikutusarvioinnin ja politiikka-analyysin tieteenaloja. Väitöskirja esittää viisi tietoyhteiskunnan liikennejärjestelmää palvelevaa tiedontuotannon muotoa ja näitä kuvaavat keskeiset piirteet, jotka on tunnistettu relevanteiksi tiedontuotannon ulottuvuuksiksi teoreettisten viitekehysten ja neljän tapaustutkimuksen avulla. Nämä viisi muotoa ovat tiedontuotanto järjestelmätason ennakointitoiminnan avulla, tiedontuotanto järjestelmätason arviointitoiminnan avulla, tiedontuotanto verkostoissa, tiedontuotanto oppimis- ja argumentointiprosessina sekä tiedontuotanto järjestelmän uudistajana. Väitöskirjassa esitetään lisäksi päätelmiä tunnistettujen tiedontuotannon muotojen politiikkaseuraamuksista ja jatkotutkimustarpeista. Väitöskirja on tyypiltään artikkeliväitöskirja, jossa neljä julkaistua tieteellistä artikkelia sidotaan yhteen erillisen, artikkelien kontribuutioita täydentävän ja kokoavan johdantoluvun avulla.

Preface

Writing this doctoral dissertation has taken me on a learning journey of triumphs, failures and near misses over many years. Now, as the journey nears its end, I feel very fortunate. I believe that along the way, I have learnt a lot about what it means to be a scientist, and that to be one is a goal worth striving for. There is a large group of people, whom I would like to thank warmly for guiding me through this journey.

First of all, I would like to thank my supervisors, professors Janne Hukkinen and Tapio Luttinen for their guidance and advice in academic research and writing. The Doctoral Seminar of the Laboratory of Environmental Protection at the Helsinki University of Technology has offered me an invaluable source for learning the secrets of academic writing. I would like to thank Henrik Bruun, Katri Huutoniemi, Maria Höyssä, Nina Janasik, Aino Kilpiö, Richard Langlais, Mikko Rask, Olli Salmi and Martti Timonen for their valuable comments and fruitful discussions over the past decade.

I would like to express my particular gratitude to Veli Himanen, who was responsible for introducing me to the fascinating world of transport policy research in the late 1990s. Since then I have had the privilege of co-operating with him on several very interesting projects. In the field of future studies, I appreciate Sirkka Heinonen for her guidance of the same kind.

I would like to thank my colleagues and co-authors of the included papers – Toni Ahlqvist, Tuuli Järvi, Jukka Räsänen and Ari Sirkiä at VTT Technical Research Centre of Finland and Jaques Leonardi and Christophe Rizet at INRETS, France – for the many good discussions, their support and words of encouragement during the period of writing. Without their contribution, this dissertation would not be as it is now. My pre-examiners, Docent Petri Tapio and Professor Bert van Wee, I appreciate for their valuable views and guidance in finalising the dissertation.

For the past ten years, I have been fortunate to work at VTT, Technical Research Centre of Finland, which has offered me a special vantage point on European transport research. I am indebted to all my colleagues at VTT for their time and encouragement whenever needed. In particular, I would like to thank Heikki Kanner and Juha Luoma for their support and words of advice in problematic situations, be it theoretical or practical. For innovative discussions and moments of laughter through many hard working days, I warmly remember Marja Rosenberg and Raija Sahlstedt. Thank you for those enjoyable moments, which have helped me discover new perspectives in my work.

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I am deeply indebted to my parents for their love and encouragement throughout the writing process. From a practical point of view, their help with childcare over the past ten years has been invaluable. The same applies to my in-laws, Anneli and Timo. Thank you all so much. My oldest and dearest friend Merja I appreciate for her invincible belief in my ability to finalise the doctoral studies.

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Otaniemi, October 2009

Anu Tuominen

Contents

Publications

The dissertation consists of the summary chapter and the following papers:

I Tuominen, A. & Ahlqvist, T. Is the transport system becoming ubiquitous? Socio-technical roadmapping as a tool for integrating transport policies and intelligent transport systems and services (ITS) in Finland. *Technological Forecasting & Social Change* 77 (2010), pp. 120–134.

II Tuominen, A., Järvi, T., Räsänen, J., Sirkiä, A. & Himanen, V. Common preferences of different user segments as basis for intelligent transport system: case study – Finland. *IET Intelligent Transport Systems,* 2007*,* 1, (2), pp. 59–68.

III Tuominen, A. & Himanen, V. Assessing the interaction between transport policy targets and policy implementation – A Finnish Case Study. *Transport Policy,* Volume 14 (2007), pp. 388–398.

IV Tuominen, A., Leonardi, J. & Rizet, C. Assessing the Fitness-For-Purpose of strategic transport research in support of European transport policy. *European Journal of Transport and Infrastructure Research*, Issue 8(3), September 2008, pp. 183–200.

Contributions of the author

Anu Tuominen has been the initiator and responsible author of each of the papers. In Paper I, both authors contributed to the theoretical as well as the empirical sections. Anu Tuominen answered for the transport system and policy analysis and Toni Ahlqvist for the roadmapping approach. In Papers II–IV, Anu Tuominen was responsible for the theoretical sections concerning the fields of Large Technological Systems (Paper II), decision-making processes (Paper III) and policy networking (Paper IV). In the empirical section of Paper II, Tuuli Järvi was responsible for the calculations regarding passenger transport segmentation, Ari Sirkiä was the initiator of the logistics concept, and Anu Tuominen, Jukka Räsänen and Veli Himanen contributed to the overall methodological development and conclusions. Anu Tuominen and Veli Himanen wrote the empirical section of Paper III jointly. Anu Tuominen answered for the main conclusions. In Paper IV, Anu Tuominen, Jacques Leonardi and Christophe Rizet were jointly responsible for the empirical section. Anu Tuominen wrote the discussion and concluding remarks.

List of key concepts

Foresight
The term foresight was introduced in scholarly journals in the late 1980s. Foresight is neither prophecy nor prediction. It does not aim to predict the future – to unveil it as if it were predetermined – but to help in building it. It invites to consider the future as something that we can create or shape, rather than as something already decided. Four characteristics distinguish foresight from other kinds of future studies such as forecasting and modelling. Foresight is action-oriented, open to alternative futures, participatory and multidisciplinary. Foresight can be envisaged as a triangle combining "Thinking the Future", "Debating the Future" and "Shaping the Future".

Information society
Information society is a society in which the creation, distribution, diffusion, uses, integration and manipulation of information is a significant economic, political, and cultural activity. Information society has also been referred to as knowledge society, network society, post modern society, post industrial society, etc. These concepts show that it is an important question in which society we live and which role technologies and information play in contemporary society.

Knowledge production
Knowledge production refers here to various kinds of practices, approaches, methods and tools, which can provide assistance in policy design or decision making. Knowledge production for policies presents how information is used and given meaning within policy design.

Knowledge society
Knowledge society refers to the use a certain society gives to information: it is a deepened and intensified version of the information society. A knowledge society creates, shares and uses knowledge for the prosperity and well-being of its people. A knowledge society is one in which knowledge becomes a major creative force. Current technology offers much greater possibilities for sharing, archiving and retrieving knowledge.

Policy
Policy is a highly flexible concept that is used in different ways on different occasions. For the purpose of this dissertation, the following definition was selected. Policy is a specific decision or set of decisions, with a common long-term purpose(s). Policy is selected by a government, institution, group (public or private) or individual from among alternatives and it includes the related actions designed to implement the policy.

Policy process (also referred to as policy development)
Policy process is a tool used for analysis of the development of a policy item. Classical decision making models distinguish between four to eight process phases, the most typical of which are: (1) problem identification, (2) agenda setting, (3) policy formulation, (4) decision making, (5) policy implementation and 6) policy evaluation (continue or terminate).

Roadmap
Roadmaps aim to provide an extended view of the future of a chosen field of inquiry. 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. The technology roadmapping approach provides a structured (and often graphical) means for exploring and communicating the relationships between evolving markets, products and technologies and processes over time. Socio-technical roadmaps provide a wider, more societal view of the future of a chosen field.

Socio-technical system
Socio-technical system is a mixture of people and technology. Socio-technical systems include hardware, software, physical surroundings, people, procedures,

laws and regulations, data and structures. Socio-technical system often refers to the interaction between society's complex infrastructures and human behaviour. In this sense, society itself, and most of its sub-structures, are complex socio-technical systems.

Technological system

Technological systems are open systems in which social, economic, political and scientific factors are interrelated. Technological systems contain messy, complex, problem solving components. They are both socially constructed and society shaping. Among the components in technological systems are physical artefacts, organisations, scientific and legislative components, and natural resources. According to T. P. Huges (1987), the evolvement or expansion of Large Technological Systems (LTS) can be presented in the following phases: invention, development, innovation, transfer, growth, competition and consolidation.

Ubiquitous (network) society

Ubiquitous society refers to the vision of a world, in which information can be accessed from anywhere, at anytime, by anyone and anything. It is hoped that new and exciting technologies will make this vision a reality. Early forms of such technologies can be seen in mobile phones, and to some extent in the broadband internet. In the future, however, it is hoped that ubiquitous networks will extend beyond person-to-person and person-to-object connectivity, uniting everyday things in one huge, ubiquitous communications network.

Vision

Vision refers to great perception of future developments or the ability to see or plan into the future. A vision can be political, religious, environmental, social, or technological in nature. A visionary can be a person with a clear, distinctive and specific vision of the future, usually connected with advances in technology or social/political arrangements. Visionaries simply imagine what does not yet exist, but might some day, as some forms of visioning provide a glimpse into the possible future.

1. Introduction

In Finland as in many other European countries, knowledge production to support transport policy development and decision making have traditionally focused on project appraisals regarding the costs, benefits, and social and environmental impacts of infrastructure investments. Recently, due to the important role the Information and Communication Technologies (ICT) have gained in our societies, similar assessments have become common in relation to ICT application projects in the field of transport as well. It can be argued that these practices have over the years developed into a field of science that could be described as a policy-driven applied science, placing scientific results in the service of society. Due to the dominance of infrastructure project investments in transport system-level planning, classical decision-making models stemming from political science or other methods with a wider social perspective have not been traditional frameworks in the field of transport.

The researchers of ICT-related social change (e.g. Anderson et al. 2007, Oudshoorn and Pinch 2003) perceive that we might currently be on the cusp of a major social and economic transition. As a consequence, the context of transport policies could also be about to shift from designing road, railway or waterway lines or networks towards the development of a complex technological system largely depending on IC technology and ICT applications (such as traveller information services, traffic management services, navigation and autonomous vehicle systems). Intelligent technologies and services are considered to have great potential, but concerns over e.g. privacy, security or public-private role divisions are one challenge out of many posed by contemporary transport. Energy and global warming issues, globalising markets, regional and urban structure developments, ageing population as well as lifestyle, consumer habit and time management changes of individuals have been named as the other major challenges (e.g. CEC 2006, MinTC 2007a, Stead 2006, Tuominen et al. 2007). One dimen-

sion in the above mentioned shift is that policy makers and other societal actors worldwide need to understand the kinds of changes that are occurring in society, although these are not necessarily visible through official statistics, for the basis of their decisions. Further, the evolving transport system includes also commercial stakeholders who need to gain an understanding of the same processes as well (e.g. Anderson et al. 2007, Rämä et al. 2004 and Tuominen et al. 2007).

In the emerging phase of the information society – the ubiquitous society – the functioning of the transport system will be based increasingly on different mobile, flexible and personalised ICT services. The new technology brought into the transport system will change the roles of the different actors within the system and the nature of strategies and measures. This development will have some impact on the ways in which people move and goods are delivered. As the transport system and the needs and preferences of its end-users evolve, policy developments supporting knowledge production should respond accordingly.

This dissertation explores and analyses the challenges and needs that developments in the information society are bringing to knowledge production supporting policy development and strategic decision making in the field of transport. My basic argument is that there is a need to broaden the understanding of the dynamics of knowledge production supporting transport policies of the information society. The conventional transport planning approaches, like cost-benefit analysis and impact assessments that apply to infrastructure projects, are by themselves inadequate for addressing the systemic challenges of future transport policy. I argue that new forms of knowledge production having a broader societal perspective are of major importance in this new context.

My particular interest concerns the challenges that knowledge production relevant to transport policy face within the context of information society development. Consequently, my general aim in this dissertation is to identify the forms of knowledge production that can serve the needs of policy development in the changing transport system context. I have chosen to refer to these practices as "knowledge production for transport policies in the information society" as distinct from the traditional transport planning presented in detail in section 3.2. I am also interested in the methods of knowledge production that transport system actors need in order to adopt these forms. The theoretical and practical implications of emerging knowledge production forms for designing better transport policies form the main conclusions of my dissertation.

My contribution to the above issues is based on four case studies (Papers I–IV), in which I have illustrated new knowledge production approaches to support

transport policies. The papers provide four different views on understanding the dynamics between the socio-technical transport system, its actors, networks, policy relevant knowledge production and decision making.

In Paper I, Toni Ahlqvist and I examine the challenges of designing transport policies on a technological frontier that is moving very quickly. Our main argument is that in order to understand the systemic and socio-technical nature of the transport system, the views of the system itself as well as the supporting knowledge production should be re-thought. We propose socio-technical road mapping as one potential method to widen the perspective of knowledge production for transport policy design.

In Paper II, together with co-authors Tuuli Järvi, Jukka Räsänen, Ari Sirkiä and Veli Himanen we highlight the importance of the preferences, needs and emergent characteristics of the different transport system end-users as a knowledge base for transport policy design. Since it is not possible to survey the preferences of each individual, we illustrate a method to categorise users of the transport system into homogeneous groups based on their differences in daily mobility and transportation of goods. These groups can provide a starting point towards end-user-oriented policy design and also initiate a more detailed analysis of end-user preferences and needs.

In Paper III, Veli Himanen and I explore the knowledge production or knowledge flow between the two important but often too distant phases of transport policy development, namely policy targets and policy implementation. In order to strengthen the often overly weak link between those two phases, as well as increase the success of policy implementation, we introduce a method called target analysis.

In Paper IV, together with co-authors, Jacques Leonardi and Christophe Rizet we discuss the fitness-for-purpose of strategic transport research conducted in the European Framework Programs. We argue that there is a need to bridge the gap between the European transport research and policy agendas. Consequently, we propose a fitness-for-purpose assessment method to provide the knowledge required for the bridge building.

However, knowledge production in support of transport policy formulation consists of multidimensional processes that cannot be extensively covered by a set of scientific papers. Hence, in this summarising section of the dissertation, my aim is to take a more comprehensive look at knowledge production in the transport domain. The structure of this dissertation is as follows: Section 2 describes the challenges that knowledge production faces in the transport policy environ-

ment of the future. Section 3 presents the theoretical premises and discussions related to knowledge production in support of transport policy, and outlines potential new approaches to knowledge production. The research questions are detailed at the end of Section 3. An overview of the methodological principles adopted in the papers is provided in section 4. Section 5, based on the main results of the included papers and the theoretical section, explores the forms of "knowledge production for transport policies in the information society", related methods, actors and their linkages. Finally, section 6 discusses the implications of the identified forms for the future of transport policy development and suggests some future research needs.

2. An evolving transport system poses challenges for policy-relevant knowledge production

In Finland, neither the notion of transport policy itself nor knowledge production supporting transport policy have traditionally been issues of wide public debate. If anything, transport policy has been perceived through its objectives, targets or policy measures identified for the achievement of the objectives. Among the Finnish transport sector stakeholders, transport policy has often been understood as meaning the construction of infrastructure, i.e. roads, railways, waterways, airports and related terminals, but in today's society also the information and communications infrastructure for transport. Another interpretation has been to see transport policy as an issue relating to the mode share of intermodal transport where the public sector has the main decision making power (Ruostetsaari 1995, Valli 1998, MinTC 2007b).

In both interpretations, transport policy has been perceived as actions of the public sector within a distinct arena of the society, i.e. transport sector, not within a wider societal (e.g. social or economic) context. The adopted perspective can be seen as a fairly natural, path-dependent way of perceiving Finnish transport policy. This is because the main duty of the administrative branch of the transport sector (namely the Ministry of Transport and Public Works, established in 1917), from the 1920s to the 1960s, was the construction of the main road network for Finland. From the 1960s towards the early 1990s, the focus shifted to increasing transport capacity (i.e. economic efficiency and fluency) of goods as well as passenger transport (MinTC 2007b, Trafiikki 2007).

A rapid increase in road traffic since the 1950s has resulted in accidents and environmental problems forming key issues for Finnish transport policy from the mid-20th century onward. Since Finland joined the European Union in 1995, also sustainability concerns of European transport policy (CEC 2001, CEC 2006) have

steered the national transport policy design. Currently, energy and global warming issues, globalising markets, regional and urban structure developments, ageing population, consumer habits, and time management and lifestyle changes are seen as the great challenges for the development of future transport systems in Finland and Europe (CEC 2006, MinTC 2007a, Prime Minister's Office Finland 2007, Stead 2006).

The efficiency objectives of the transport and logistic systems are still on the agenda, albeit framed into a new form. According to the Finnish Government[1] and the European Commission[2], Intelligent Transport Systems and Services (ITS)[3], also called transport telematics, will – whether they already exist or are due on the market in the near future – gradually provide new services to citizens and allow improved real-time management of traffic movements and capacity use. It is hoped that the new systems will offer benefits to transport operators and end-users, but also provide public administration with rapid and detailed information on infrastructure and maintenance needs. In addition to enhanced travelling and transportation comfort, it is argued that they will also help both increase transport safety and security and tackle wasteful transport patterns in the interests of environmental sustainability. The Working Group on ICT for Clean and Efficient Mobility (2008) believes that there is substantial untapped potential for a new generation of Green ITS technologies, applications and services (such as eco-traffic management, eco-information and guidance, eco-demand and access management, eco-freight and logistics management) whose primary purpose is to reduce environmental impacts or increase the energy efficiency of road transport.

The above suggests that the context of transport policy development is about to shift from a path-dependent network design towards development of a complex technological system, largely depending on ICT technology and applications. The challenge is how to recognise the changes in the system and its environment as the basis for the system and policy developments.

Richard Bolan (2007), for example, suggests that information workers (20 percent of the workforce in year 2000) have a particularly strong influence on transport systems because they tend to be clustered in terms of where they work but

[1] Prime Minister's Office Finland 2007

[2] CEC 2006, CEC 2008

[3] Information and Communication Technology (ICT) applications for transport

not where they live, and also tend to commute longer distances from home to work. Bolan has noticed that information workers spread out in a very controlled way, like Route 128 near Boston or in the Silicon Valley, in the U.S. He sees information workers as the future's "city shapers" by claiming that where policy leaders place highways can shape how the economy of a region takes form.

Another example relating to the former one is to recognise new, emerging forms of utilising existing transport networks. One of these is to turn commuter trips into office hours with the help of company buses. The Internet company Google, for example, ferries in about 1,200 employees, nearly one-fourth of its local work force, to and from Google daily in Silicon Valley. The service includes around 32 free shuttle buses equipped with comfortable leather seats and wireless Internet access. Riders can sign up to receive alerts on their computers and cell phones when buses run late. The employees also promote environmental sustainability, not just for ditching their cars, but because all Google shuttles run on biodiesel (Helft 2007).

In Finland, ITS development relates to Finland being a paradigmatic information society due to the fast rise of the Finnish ICT sector during the 1990s (Castells & Himanen 2002). 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 (Häyrinen-Alestalo et al. 2004, Pelkonen 2003). In the vision of the Finnish information society, the role of information technology and data networks is to bring forth efficiency, organisational renewal and new forms of collaboration as well as promote the network economy by opening up the development of new services and industries (Ministry of Finance 1995).

One of my principal claims (Papers I and II) is that in the context of the information society's transport system, it is too seldom emphasised that a transport system is not just physical networks or about physical networks. A transport system, whether international, national or local, is a large technological system that contains messy and complex components. It is a socio-technical network. The state of the transport system is a result of the measures and actions carried out by the producers, operators and users of the system, who in turn shape the system by their own behaviour and actions. The system is thus both socially constructed and society shaping (cf. Hughes 1987). The challenges of the strong ICT push and its social implications have been examined e.g. by Anderson et al. (2007) and Oudshoorn & Pinch (2003).

In Finland, the role of citizens has so far been rather limited, as the public has not been seen as a contributor to policy making but rather as the object of policy – besides having the role as consumers and users of end products. The shift toward market governance in ICT and consequently in ITS has, however, resulted in increasing interest in consumer needs and preferences as a basis of transport technology design (Paper II). Early signs of a similar interest in placing end-user needs as the first priority have also been emerging within the context of Finnish policy design (Jalasto et al. 2007, MinTC 2007a).

On the other hand, it seems that the world is becoming an increasingly turbulent information society, and too fast – faster than the structures of private and public organisations or even private lives are able to become resilient (Papers I and III). In the transport context, this means that while there are no general restrictions for developing and supplying Intelligent Transport Technologies and Services from a technological point of view, users are still quite slow or even reluctant to accept new intelligent products and services (Paper II). This relates also to the dilemma between ITS and sustainable development. The pace and scale of these focal areas of contemporary transport policies often seem to be very different.

OECD governments and the media today remind us at almost every turn that knowledge production has an enormous, foundational role in our lives in the information society or, further, in the knowledge society. Based on Paper I, in which I and my co-author have identified the features of current and future societies in the context of transport policy, I argue that the main socio-technical principles of the transport system are likely to evolve as follows.

In the contemporary information society, the physical transportation principle is increasingly concentrated on the flow of bits in cables. However, also traditional transport flows are still increasing due to globalisation and growing networks of companies and individuals. In the following societal phase – the knowledge society, as we propose in Paper I – the produced information will be put to use. The knowledge society will share and use knowledge for the prosperity and well-being of its people. Here knowledge becomes a major creative force. During this phase, an immaterial transportation will become a true option. The transport system will be governed increasingly by ICT-based management solutions. To support the development and functioning of the system, also new forms of knowledge production will be needed.

Based on our view of societal transformation in Paper I, in the next – ubiquitous – phase of society, one will start to highlight transparency as the key socio-technical principle. The transport system will become a truly 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 will change and we can start to speak of a new, transparent operation mode or "technology services". Technology services can be defined as combinations of technologies and services enabled by interlinking the static transport system and the information infrastructures, information gathering, processing and delivering, as well as its mobile stakeholders like people, goods and vehicles. Technology services will be the products of a society utilising ICT as its basic infrastructure and service platforms. They will be tailored for different kinds of purposes based on the continuous communication between actors in the transport system.

The emergence of new intelligent technologies and services will bring new challenges to decision makers, researchers, businesses, and other societal actors. Intelligent technologies and services will also affect the nature of schemes, strategies and measures as well as the roles of the different actors within the transport system. The roles of public and private parties in the transport system will intermingle in different ways, with new operational practices, and new policy and business models will arise. This development will have some impacts on the ways people move and work and how goods are delivered. The accelerated pace of information society life and business styles will affect also the daily time budgets for travelling. The existence of fixed daily travel time budgets, for example, is an ongoing subject of scholarly debate (e.g. Metz 2004, Höjer & Mattsson 2000, Schafer 2000).

I argue that these are the main challenges we need to face in designing contemporary and future transport policies on, as it seems, a rapidly advancing technological frontier. One of the most problematic questions is how to combine broader societal needs and the dominance of market governance in developing transport policies of the future. Further, what are the particular implications of these socio-technical challenges for knowledge production supporting transport policy formulation?

In the following section, I take a closer look at these questions by first examining the theoretical premises of current knowledge production supporting transport policies. Second, I present some emerging knowledge production approaches from other disciplines that I see as having potential also in the transport sector.

3. Theoretical considerations

3.1 Knowledge production to support transport policies

Science and technology studies (STS) is a field that has aimed to illuminate the relationship between scientific knowledge and political power, as well as investigating the place of science and technology in society over the past few decades (Jasanoff 2004). In the discourse of STS a distinction is often made between basic science, driven by curiosity and the desire to expand knowledge for its own sake, and applied science that places scientific results in the service of society (Jasanoff 1990, Lövbrand 2007). In my view, knowledge production to support transport system developments and decision making cannot be categorised into either of these branches, but into a third one which has interested science and technology scholars since the 1970s. This third branch of science is closely related to applied science, but is more policy driven and has been referred to as "trans-science" (Weinberg 1972), "regulatory science" (Jasanoff 1990) or "fiducial science" (Hunt & Shackely 1999). Recently, this branch has been closely studied and elaborated further, for example in relation to environmental regulation (e.g. Jasanoff 2004, Lemos & Morehouse 2005, Lövbrand 2007).

To my understanding, within this third branch of science, knowledge production to support transport policies and decision making have traditionally focused on project appraisals regarding the costs, benefits and environmental impacts of physical transport project (e.g. infrastructure) investments. I have chosen to refer to these as "traditional transport planning".

With that background, in subsequent sections I first present the theoretical backgrounds of traditional knowledge production used for policy support in the transport domain, "traditional transport planning". After discussing their deficiencies in information society contexts, I review some other knowledge production

approaches, which provide a wider, more societal approach for policy support and which seem to hold some promise also for the transport domain. These approaches include policy analysis, systemic planning, integrated assessment, mode 2 knowledge production and the concept of co-production. I formulate my specific research questions in the final section of this chapter.

3.2 Transport planning – the traditional knowledge production approaches to support transport policies

The rational approach as a knowledge production practice for the transport domain evolved in the early 1960s and has ever since, with minor variations, served as the main purpose and methodology for transport planning and decision making. 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 (Meyer & Miller 2001, Pearman et al. 2001 and 2003, TRANS-TALK 2001).

Within the traditional transport policy and project planning approaches there exists a wide range of different assessment methods or tools for data collection, analysis and formal assessments. Typical methods used for data collection are surveys, before-and-after studies, use of secondary data, existing databases, case studies, expert opinions, program documents and literature reviews. Statistical analysis, transport models (based on micro- and/or macro-economic models), transport forecasts, expert panels and benchmarking are examples of current data analysis methods. 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. Layard & Glaister 1994, Pearce & Nash 1981, Sugden & Williams 1978).

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 as sufficient to ensure the multifaceted understanding of a plan or policy that is increasingly required (Dodgson et al. 2000). 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. Due to the development of ITS and interest in and use of Human-Machine Interface (HMI) design, user requirements and specific field tests have increased. This applies also to ex-ante and ex-post assessments of technical applications as well as larger systems. Sometimes also, Delphi and Beneficiary surveys and SWOT analysis have been used in obtaining data and observing changes in the transport field.

Basically, the objective of these approaches has been to break down the planned transport project into thematic components (e.g. environmental, economic and social) and give those components numerical values, on the basis of which analytical assessment and comparison of different solutions have been conducted to find the optimal one. The intention has been to provide premises for rational societal decision making. These formal techniques have a strong technological basis and, partly as a consequence, a strong institutional basis as well. In most European countries, mandatory assessments such as Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) regarding new transport infrastructure projects are examples of that field. The approaches have been mostly inter-urban, only rarely responsive to interactions outside the transport sector and hence not consciously oriented towards wider societal, e.g. sustainability concerns (e.g. ECMT 2004, Nijkamp & Blaas 1994, Pearman et al. 2001 and 2003, TRANS-TALK 2001).

The above implies that in the field of transport, the terms ”planning” and ”(impact) assessment” referring to infrastructure investments and project appraisals have formed the policy support frameworks for decades (Giorgi et al. 2002, de Rus & Nash 1997). Consequently, knowledge production serving transport policy has focused on “checking plans for public expenditures” (de Rus & Nash 1997), for estimating time savings, for investigating mainly at the macro economic level the relation between infrastructure investment and urban or regional development (Banister & Lichfield 1995), or for assessing social and environmental impacts (Hoon Oum et al. 1997). The development and use of policy level approaches (such as policy analysis) is still a new, emerging field in the transport context, even though it has been on the agenda for a long time.

Juri Pill (1978), for example, argued already in the late 1970s that transport planning needs more detailed, comprehensive and objective observation and less theorising. He presented also the main planning paradox: striking the balance between rigorousness and usefulness. If the transport planner wants to influence the

decisions, he or she must sometimes set aside the comprehensiveness of the analysis and deal with the issues as they occur. If he or she chooses the more rigorous, academically correct course, the advice will arrive too late. In the 1980s e.g. Alexander (1984) Christensen (1985) and Himanen (1987) criticized the traditional rational models for policy design and decision making, based on the best available information, and stage-based proceeding as being unrealistic in tackling the problems of goal consensus, information processing and the nature of information itself within the changing environment.

The multiplicity of methods complemented with the complexity of the transport environment has been seen to pose severe problems for knowledge production relevant to transport policy. The complexity involves at least the dimensions of scope and timing. With regard to geographical scope, one has to distinguish at least between international, national, regional and local levels. The time dimension is considered important in two ways:

First, the timing with regard to the phase of project or policy development. In transport assessment or evaluation literature (e.g. Giorgi & Tandon 2000, Giorgi et al. 2002, JEGTE 2003, Layard & Glaister 1994, Minken et al. 2003, Pearce & Hett 1999, Pearman et al. 2003, Sugden & Williams 1978, TRANS-TALK 2001, Turro 1999), one refers alternatively to *ex-ante assessment or appraisal* to describe assessment carried out during the planning or policy formulation phase. The primary function of appraisals is to deliver insights into the expected outputs, results or outcomes of the project or policy. Assessment carried out during implementation or the decision-making phases – often referred to as *mid-term assessment or monitoring* – has the function of observing developments to deliver the preliminary assessment of the project's or policy's effects or of the extent to which it is proceeding according to original plans. The third assessment type carried out once the project or policy implementation has been completed is often given the name *ex-post assessment or evaluation.* Its function is to supply policy makers with information about the results and outcomes of the projects or policies. Second, and in addition to the above categorisation, the time dimension is considered relevant in presenting the time horizon for which project or policy effects are to be observed or forecast.

Currently, according to the European Thematic Network: 'Policy and Project Evaluation Methodologies in Transport' TRANS-TALK (2001), Giorgi & Tandon (2000), Giorgi et al. (2002) and Pearman et al. (2001 and 2003), there are two views about what role knowledge production (especially assessments) to support transport policies should have. One is simple: they are tools to assess value for money. An al-

ternative view is that they are tools to help in the negotiation and deliberation process, through which socially desirable transport actions are identified.

Meyer & Miller (2001) support the latter view and argue that the decision-oriented transport planning approach, for which different methods provide information, should address a much wider range of issues. These include: establishing the future context; responding to the different scales of analysis; expanding the problem definition; maintaining flexibility in analysis; providing feedback and continuity over time; relating to the programming and budgeting process; and finally providing opportunities for public involvement. Also Short & Kopp (2005) present a critique of current (mega) project appraisals. They observe that project appraisal is inconsistent and weak, strategic appraisal is in its infancy, ex-ante appraisal is often biased and ex-post analysis rarely takes place. They suggest (as do some other contributors in Priemus et al. (2008)) that research into planning and decision-making processes could, given their ever-increasing complexity and duration, be of great value to society.

The above arguments are complemented and elaborated e.g. by Tuomi (2001, 2003), who has defined the three research domains of knowledge society that are linked to core developments in the ongoing transformation or change. 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 the introduction of wider, multidisciplinary approaches also to support all phases of transport policy development (e.g. ECMT 2004, Giorgi et al. 2002, TRANS-TALK 2001, Tuominen et al. 2007).

My basic argument in this dissertation is that traditional transport planning is no longer sufficient to provide the knowledge needed to understand the socio-technical nature of the transport system – and the dynamics between the different actors within – as a basis for transport policy development. For example, in the information society's transport system the roles and networks of stakeholders will be pluralised. The transport system will be increasingly composed of public parties, private parties, contributing end-users and their complex networks. In Paper I we suggest that in the future, all actors within the transport system will equally produce and use the produced knowledge as the basis of their actions, business, and policy development. This requires re-thinking also of the knowledge production approaches.

Frameworks for bounded rationality and experiential incrementalism, referred to in Paper III, and also Valovirta & Hjelt (2005) complement my view by ob-

serving that traditional formal knowledge production techniques are often based on assumptions which may not be accurate; e.g. the policy maker is assumed to be a rationally acting individual, and choices are clearly demarcated or decisions non-recurrent. My view is that very seldom are formal assessment techniques capable of producing comprehensive answers to practical questions. To serve the transport policy development of the future, knowledge production will need to take into account also the socially constructed and systemic nature of the transport system. This requires further shifting of the decision making from the actual decision-making situation to the future (foresight) on the one hand and the past (evaluation and monitoring) on the other. To my understanding, assessing the long-term and broad scale policy outcomes as well as the effectiveness of the proposed policies is of great importance here. Knowledge production does not need to provide a solid basis for decision making as a result, but act more as a process of social argumentation. The new knowledge can be seen as a fuel feeding the already ongoing processes, and individuals or organisations will gain added value by participating in the processes.

3.3 Policy analysis

The academic field of policy analysis is an old, traditional way of policy-relevant knowledge production. Understood in its widest sense, policy analysis is as old as civilization itself. It emerged at a point in the evolution of human societies where practical knowledge was consciously cultivated, thereby prompting an explicit and self-reflective examination of links between knowledge and action (Dunn 2004). One of the earliest recorded efforts to consciously cultivate policy-relevant knowledge occurred in Mesopotamia, in the twenty-first century B.C. The early Mesopotamian legal codes were a response to growing complexity of fixed urban settlements, were policies were needed to regulate the distribution of commodities and services, keeping records and maintaining security and defence.

Basically, as defined in political science, policy analysis is a term used to cover all methods or approaches that can be used to make any form of judgement on public policy (Birkland 2001, Dunn 2004). In other words, it can be described as a multidisciplinary, problem-solving process designed to create, critically assess, and communicate information that is useful in understanding and improving policies. Policy analysis may regard economics, environment issues, decision-making processes, organisational aspects, etc., and it has been applied in many fields of society such as health, education, housing and work.

In political science the policy cycle or policy process is a tool used for analysing the development of a policy item. Classical decision making models (e.g. Birkland 2001, Dunn 2004, Dye 1976, deLeon 1999, Lasswell 1956, Palumbo 1987, Parsons 1995) distinguish between four to eight process phases, the most typical of which are: (1) problem identification, (2) agenda setting, (3) policy formulation, (4) decision making, (5) policy implementation and 6) policy evaluation (continue or terminate).

Traditionally, the main purpose of policy analysis has been to improve the policy making process by producing knowledge for the different phases of the policy processes. According to Dunn (2004), policy analysis aims to produce five types of policy-relevant information. These types represent information about policy problems, policy performance, expected policy outcomes, preferred policies and observed policy outcomes. These five types are interrelated. Five policy analysis procedures produce and transform the information: *problem structuring* produces information about what problem to solve, *forecasting* about expected outcomes of policies, *evaluation* produces information about the value or worth of expected and observed outcomes, *monitoring* produces information about observed outcomes of policies and *recommendations* about preferred policies.

Furthermore, in policy analysis literature, one may distinguish between different forms of analysis. As in the context of transport planning (discussed in section 3.2), prospective (*ex-ante*) policy analysis involves information production *before* policy actions are taken and retrospective *(ex-post)* analysis involves information production *after* policies have been implemented. Other forms identified for policy analysis are descriptive or normative, problem-finding or problem-solving and segmented or integrated analysis.

Some scientists and practitioners in the field of transport observe that policy analysis could be successfully applied also to the transport sector (e.g. Giorgi et al. 2002, TRANS-TALK 2001). However, when looking at the knowledge production needs of the transport systems of the future, my claim is, that despite providing a wider perspective than traditional transport project assessments, policy analysis would by itself fall short in taking into account the many different actors and emerging actor clusters that produce and need knowledge within the information society's policy processes. The original aim of the policy analysis has been, however, to serve "traditional" institutionalised policy making, which justifies this kind of reflection.

There are also other features, which my co-authors and I have identified as important for future knowledge production in transport policy, but are missing from

the approaches presented in the previous sections. The first one is the ability to see transport systems as common pool resources developed by various clusters of actors and end-users. Papers II and III take two different perspectives on this issue, namely needs and preferences of different end-user segments as well as policy target analysis and elaboration. The second one, a consequence of the former, is the lack of interest and forums for co-operation in building common future visions for transport sector developments within the wider societal context. The issue is highlighted especially in Paper IV.

3.4 Systemic planning

Systemic planning (SP) by Steen Leleur (2008) is an approach developed for planning under complicated and difficult circumstances. The basic ideas of SP stem from the third wave of systems science (from the 1990s to the present) and draws on the theoretical work primarily done by Luhmann (1995), Morin (1992), Dreyfus & Dreyfus (1988) and Stacey et al. (2000). The third wave of systemic science is characterised by uncertainty, chaos and complexity. SP is basically built on the last complexity orientation. Systemic planning refers to the emerging new type of 21st century society as the hyper-complex society.

The systemic planning approach emphasises that reorientation from conventional, analytical stage-based planning (see section 3.2) to a wider, systemic, communication-based, decentred social systems thinking is needed under complex conditions. Seeing planning as a non-linear process and contingency as its main condition are the basic ideas behind the SP approach.

Building awareness of the complex conditions, as well as creatively building processes for the systemic approach, are the key tasks in systemic planning. SP consists of an exploration and learning cycle that in an ongoing, self-organising process establishes a "sub world" around the planning problem (Leleur 2008). The key notion, and what creates the sub-world is the successive recasting of systemic perceptions. The various insights identified and the way these insights are confronted, interpreted and combined determines the achievement of the systemic perception of the problem, the "difference" from the previous one.

Furthermore, Leleur presents four SP planning concerns, which can assist the planning processes as follows: (1) adequacy, which illustrates the feasibility of the action, (2) dependency, representing context feasibility, (3) suitability, representing action acceptance and (4) adaptability, representing context acceptance. Both hard and soft operations research methods can be used in testing the above concerns. The

approach has been applied to and examined in the context of transport infrastructure planning (The Øresund Fixed Link 2005), but the methodology seems to be generally applicable to other sectors of society with a need for systemic decision support due to uncertainty and complexity (Leleur & Holvad 2004).

Even though SP presents a new, wider, systemic approach to transport planning, the focus is still on transport infrastructure project planning, not on developing the socially constructed and society-shaping transport system. This, I consider to be one of the main issues in producing knowledge in the information society context. It allows me to propose the forms for knowledge production that I present in this dissertation as complements to the SP approach.

3.5 Emerging knowledge production practices

3.5.1 Background

In the previous sections, I presented the traditional and emerging approaches to support transport planning and policies. In addition, I discussed their potential and deficiencies in serving the knowledge needs of the emerging socio-technical transport systems. In the following sections, I review some emerging knowledge production practices from the field of Science and Technology Studies (STS) that I see as relevant also for the transport sector, namely: integrated assessment; co-production and mode 2 knowledge production. The reason for choosing these approaches lies in their nature and ambition to explore how knowledge production is incorporated into practices of policy making or of governance more broadly and, conversely, how practices of governance influence the making and use of knowledge (Jasanoff 2004). I consider this a very important but missing perspective in current knowledge production in the transport domain.

As discussed in section 2, traditional institutionalised knowledge production and mechanisms in the field of transport are no longer – and will be even less in the future – sufficient in serving policy development processes, which are themselves also evolving. As Jasanoff (2004) puts it, deeper understanding between the transport domain and others such as STS, politics, environmental protection, economics, sociology etc. about the links between knowledge, power and culture are needed and could be enormously fruitful. I see that understanding these links could clarify also the roles and relationships of different transport system actors in the information society's transport domain, not as such but as part of a wider socio-technical system.

3.5.2 Integrated assessment

An emerging assessment approach, complementary to the traditional policy analysis and claimed to have potential also within the transport sector, is the concept of Integrated Assessment. When first introduced in the mid-1990s (e.g. Gough et al. 1997, ICIS 1999, Rotmans 1998, Rotmans & Dowlatabadi 1998), Integrated Assessment (IA) was referred to as "the new fashion in scientific research for policy making purposes". IA suggests that since the world around us is becoming increasingly integrated in its commercial, financial and social activities, the consequent complexity forces us to think and act in a more integrative manner.

Hence, IA has been delineated as a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision makers. It tries to shed light on complex issues by illuminating different aspects of the issue under concern: from causes to impacts, and from options to strategies. IA partly overlaps with the existing research areas, especially technology assessment, risk analysis and policy analysis. However, these research areas also address some kind of complex problem from a specific point of view. The essential difference is that IA aims to integrate knowledge from an *a priori* integrated point of view (Rotmans 2006 and 1998).

Further, IA has been described as an iterative, continuing process, where integrated insights from the scientific and stakeholder community are communicated to the decision making community, and experiences and learning effects from decision makers form one input for scientific and social assessment (Rotmans 1998). The IA toolkit includes both analytical tools/methods (such as scenarios, models, risk analysis) and participatory methods (such as focus groups, policy exercises and dialogue methods). IA methods have been developed by e.g. Rotmans (1998); Rotmans & Dowlatabadi (1998); Toth & Hizsnyik (1998) and Toth (2003). They have been successfully applied especially in the field of Climate Change.

Currently, the IA theorists (e.g. ICIS 1999, Rotmans 2006) see that the first generation of IA tools described above were quite technocratic and deterministic by nature, with a high level of engineering and often considered as "truth machines". The next generation tools should focus on their exploratory rather than predictive value. Also, they should be considered more as aids to gain more insight into and achieve better understanding of the persistent problem in question and should be built by networks and collaborations between different institutions.

Sustainable development as an overarching policy target is seen as a major initiator for these needs. The key requests of also the systemic planning approach (in section 3.4) – building awareness about the complex conditions and creatively building processes for a systemic approach – relate closely to the needs of IA, strengthening the demand.

There are at least four complementary approaches, which have been suggested to alleviate the demand (Rotmans 2006, ICIS 1999). The first is interlinking and improving existing tools. The main issues identified here are interlinking the different existing assessment tools to enable estimation of how policies contribute to specified objectives and targets, using tools in conjunction with relevant indicators and scenarios, improving the presentation (visualisation) and documentation of the tools and the communication of disciplinary researchers and gaining more experience with participatory methods.

Our focus in Paper III relates closely to the issue of estimating how policies or policy measures contribute to specific targets. We see that the method we have developed for target analysis in the transport context could contribute also to other fields, especially IA since the transport system is a socially constructed and widely integrated large technological system. Also, in Paper IV there are similarities with the above requested issues, namely using assessment tools with relevant indicators and scenarios. We found that in the context of the European Commission's transport research projects there has been a definite lack of linkages between developed indicators and different assessment tools.

The second approach is developing new tools and instruments. Here it is seen that the new tools should handle multiple scales, especially to link micro and macro scales and deal with the dynamic behaviour of stakeholders. The tools should be rooted in complex systems theory, evolutionary economics, multi-level governance and multi-agent modelling. They should also integrate science better and be more explorative than predictive. Our approach in Paper II is to illustrate how categorisation of transport system's end-users, based on their differences in daily mobility and transportation of goods, could be used as a basis for end-user-oriented transport policy design. In addition, we discuss the possibility to use the categorisation as a starting point also for identifying end-user's preferences for new technology in the transport system. This approach can be seen to answer especially the micro-scale dynamics requests of the next generation of IA tools.

The third suggested approach is to match better the demand and supply of IA studies. At present, most IA research is supply-driven and analytical and participatory IA tools are not used in a complementary way. The major challenge here is

seen as letting non-scientists or stakeholders co-develop analytical tools in a well-led participatory learning process. This could increase the credibility, trust and also use of these methods. My contribution to this issue is in Paper I, in which I and my co-author develop and test a participatory foresight method, socio-technical roadmapping, and identify the future knowledge needs for the transport system and policy development.

The fourth approach is developing quality criteria for IA studies. Analytical, methodological and usability criteria are the three distinguished quality criteria types. In Paper IV we consider and contribute especially to the usability criteria by developing and testing a fitness-for-purpose method for transport research projects in policy support.

The field of transport has often been mentioned, mostly because of its societal nature, as a potential field for integrated assessment. Despite this, the use of IA within the transport sector and the contribution of transport research to IA have thus far been modest.

3.5.3 Co-production and mode 2 knowledge production

In the following, I briefly review two other emerging approaches of knowledge production, namely co-production and mode 2 knowledge production, and discuss their implications for the transport domain.

The concept of *co-production* has been introduced in the field of STS, labelling a research arena where, in contrast to both basic and applied science, the primary audience are policy makers and regulators rather than scientific peers. Jasanoff (2004) defines the aim of co-production as making available resources for thinking systematically about the processes of sense-making through which human beings come to grips with worlds in which science and technology have become permanent fixtures. The aim is not to provide deterministic causal explanations or rigid methodological templates for future research.

Some (e.g. Hunt & Shackley 1999, Lemos & Morehouse 2005) have used the co-production concept to refer to the institutionalised practices by which ”usable science” is co-produced in the context of everyday interaction between scientists, policy makers and the public. Further, Lemos and Morehouse (2005) propose a concept of iterativity as a model for co-production of science and policy through integrative science. According to the model, substantial commitment to the three identified components is required. The components are: interdisciplinarity, stakeholder participation, and production of knowledge that is demonstrably usable.

The usability request relates closely to the usability criteria demand of the IA studies. In addition, resource availability, flexibility, and the level of fit between science and stakeholder needs and expectations interact with the three components to either facilitate or limit the scope of co-production in different situations. My co-authors and I discuss the production of usable science in the context of European transport research projects in Paper IV, by using the term fitness-for-purpose.

Others have referred to co-production as the dynamic process by which science and society continually shape, constitute and validate one another (e.g. Jasanoff 2004, Jasanoff & Wynne 1998, Latour 1987). Bruno Latour (1998) suggests the notion of "collective experiment", meaning that the old culture of certainty associated with pure science has been replaced by a culture of research in which science and society search for solutions collectively. Latour sees that what has changed most is the way science enters a society. It no longer enters it to bring order or simplify its composition; it enters to add new, uncertain ingredients to all the other ingredients to the collective process, to make "collective experiments".

Jasanoff (2004) identifies the following four pathways or instruments by which co-production most often occurs and operates at the nexus of natural and social order. Making identities refers to the importance of forming and maintaining of identities. What roles do knowledge and its production play in shaping and sustaining the social roles (e.g. researcher, expert or civil servant) or giving them power and meaning? In Paper I, we touch the issue by identifying the roles of different transport system stakeholders within a road mapping exercise in the context of technology services. Forming identities is referred to also in Paper II, although in a very different form. Paper illustrates the identification of the main end-user groups of the Finnish transport system for the basis of policy development, based on differences in daily mobility patterns.

According to Jasanoff (2004), making institutions emphasises that when contexts and knowledge change, new institutions emerge to provide the web of social and normative understanding within which new characterisations can be recognised and given political effect. Making discourses proposes that solving problems frequently takes the form of producing new languages or modifying old ones to find words for new phenomena, persuade a sceptical audience, link knowledge to practice or action, give account to experiments, etc. Finally, making representations refers to the fact that much work has been done on the means by which scientific representations are produced and made intelligible in diverse communities of practice, but the connections between this work and political and social representa-

tions have not always been apparent. In Paper IV, building researcher-civil servant networks around European transport research project assessments and dissemination of results is presented as a one possible solution to alleviate the problem.

Currently, one of the new knowledge production practices possibly most widely referred to and closely related to co-production is the so-called *mode 2 knowledge production*. In the discussion about mode 1 and 2 knowledge productions by Gibbons et al. (1994) and Nowotny et al. (2001), a number of attributes have been identified which suggest that the way in which knowledge is currently being produced is beginning to change. Mode 1 is presented as more or less synonymous with what has traditionally been called science. Within mode 1, knowledge is produced primarily under highly institutionalised conditions, e.g. universities, colleges, research institutes, protecting scientists from external demands. The emphasis is on differentiation, making distinctions between research fields and drawing boundaries between disciplines.

Mode 2 instead puts great emphasis on the significance of "social" in the practice constitution of science. By this it implicates that science can no longer be regarded as an autonomous space clearly demarcated from the "others" of society, culture and economy (Nowotny et al. 2001). Attributes in mode 2 knowledge production include transdiciplinarity, heterogeneity and organisational diversity, social accountability and reflexivity, quality control and, last but not least, knowledge produced in the context of applications. By application I do not mean the traditional product development and the processes. In mode 2, knowledge is always produced in a complex context, is shaped by diverse sources of supply and demand, and is not produced unless and until the interests of various stakeholders are included. These processes specify what is meant by the context of application. In Paper I, we have highlighted the issue by illustrating what kind of technologies, services, actors and related policy relevant knowledge is needed in transport system and policy developments of the ubiquitous society of the future.

The second attribute of mode 2 knowledge production is transdiciplinarity, which means that the final solutions will normally be found beyond any single discipline. The third attribute, homogeneity and organisational diversity, means that knowledge production is heterogeneous in terms of the skills and experience people bring to it. The composition of a problem-solving team changes over time; teams are not firmly institutionalised. People come together in temporary work teams and networks (arenas), which dissolve when a problem is solved (Gibbons et al. 1994).

Social accountability and reflexivity mean increased sensitivity of scientist and technologist to the broader implications of what they are doing. In other words, it refers to a growing awareness about the variety of ways in which advances in science and technology can affect the public interest. Due to this, different individuals and groups that have traditionally been seen outside the scientific and technological system become active agents in the definition and solution of problems and in the evaluation of performance. The transport system end-user groups illustrated in Paper II are examples of such new groups that may turn out to be very important information providers in the future. Finally, and endorsing the IA and co-production approaches, the criteria used to assess the quality of the work and the teams that carry it out are much broader in mode 2 than in mode 1 knowledge production.

3.6 Research questions

The discussion in previous sections has revealed some of the problems, questions and development needs, but also possibilities regarding knowledge production supporting transport policies in an information society.

On the one hand, traditional transport planning seems no longer to be sufficient in providing the knowledge needed to understand the socio-technical nature of the transport system and the dynamics between the different actors within, as a basis for transport policy development. On the other hand, new emerging knowledge production approaches are highlighting issues such as dynamic behaviour of actors, social accountability, handling multiple scales, exploring the future, linking participatory and analytical methods, developing quality criteria, etc. Therefore, there seem to be both practical and theoretical reasons to explore what kind of forms knowledge production supporting transport policies of an information society should have, and how these differ from those of traditional transport planning. For this purpose, I formulate my research questions as follows:

1. What kind of challenges and opportunities does the changing transport system pose to knowledge production approaches and contributing actors supporting transport policy development and decision-making?
2. What are the emerging forms of knowledge production that can serve the needs of policy development and decision making in the changing transport system context?

3. What are the theoretical and practical implications of the new knowledge production forms and their characteristics for different transport system and policy stakeholders?

Understanding the dynamics of knowledge production within the information society's transport system, and finding ways to fit the produced knowledge for the purposes of the development of contemporary and future transport policy, form the motivation for the research questions.

4. The approach

A variety of knowledge production methods or practices relevant to transport policy have been developed in the papers of this dissertation. The methods themselves constitute the main results of the papers. Even if the backgrounds of the papers are quite different, each paper stems fundamentally from the lack of wider, communication-based knowledge production methods to support policy development of a complex, socio-technical transport system.

In each paper, the basic approach is based on empirical material that has been used to test the potential of the developed method. In addition, a specific theoretical framework has been applied in the papers to enrich empirical analysis as well as to contribute to methodological development in the field of knowledge production for transport policy. The approaches aim to respond to both practical and theoretical needs of the information society's transport system and policy developments presented in sections 2 and 3. The papers present illustrations of the emerging forms and new characteristics, contributing actors and networks for knowledge production supporting transport policies of the future. In the following sections, I briefly present the approaches and the material of the papers included in this dissertation. Further, I discuss their contribution to the research questions.

In Paper I, we developed a foresight method – labelled visionary socio-technical roadmaps – to study the changing transport system and knowledge production needed to support transport policy development. In general terms, roadmaps aim to provide an extended view on the future of a chosen field of inquiry. 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. Kostoff & Schaller 2001, Phaal et al. 2004, Probert & Radnor 2003, and Rinne 2004). Visionary socio-technical roadmaps developed in Paper I aim for these basic roadmapping objectives with a wider view by (1) emphasising the

application visions that are embedded in the roadmap structure and (2) combining different layers of society and technology (Ahlqvist et al. 2007). The presented roadmapping process comprises three phases: (1) background study, i.e. review of existing documentary material, (2) two participatory workshops of researchers, civil servants and technology developers and (3) reporting and presentation of final results. As a result, three complementary, visionary roadmaps within a time frame up to the year 2025 have been produced. The roadmaps consist of five layers: user needs, markets, actors, technologies and assessment knowledge.

The approach in Paper I contributes mainly to the research questions 1 and 2 by illustrating the future developments of the transport system technology services through user needs, markets, participating actors, technologies and the required policy relevant knowledge. Traditionally, roadmaps have 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 my main field of interest, the roadmapping method has not been commonly applied. Based on Paper I, with the Finnish case study, I argue that visionary socio-technical roadmapping can provide a tool for a better understanding of the socio-technical and systemic nature of the transport system as well as bringing transport system actors together to discuss future transport visions, policies, technologies, services and their interdependencies in a collaborative manner.

Paper II contributes to the methodological development of end-user-oriented transport policy-relevant knowledge production. Since it is not possible to survey the mobility needs and preferences of each individual transport system user as a basis for end-user-oriented policy design, the paper illustrates, through a Finnish example, the possibility to categorise users of the transport system into homogeneous groups based on their differences in daily mobility and transportation of goods. In addition, the potential to deepen this segmentation to illustrate the acceptance by different user groups for new transport technology or policy is discussed. The theoretical background of the paper stems from the framework of the LTS (Large Technological Systems) theory developed by Thomas P. Hughes (1987 and 1983) which is complemented by the Social Construction Of Technology (SCOT) approach of Pinch & Bijker (1987).

The empirical data for passenger transport categorisation stems from Finnish national household surveys and demographics. The aim of the approach is to classify the whole population into a minimum number of person groups by their demographics, using differences in daily mobility as the criteria. The motivation behind the exercise was to find homogenous groups, whose mobility needs could

be investigated further, e.g. with a survey or interviews, as the basis for policy developments. The analysis was started with around 100 person groups, which through various mergers were reduced to 11. Furthermore, the potential to deepen this segmentation to describe the needs of – but later in the policy process also social acceptance by – different user groups for new transport technology or policy was examined. The strength of this classification method can be seen in its extensive but also simple nature. First, the extensive data and large number of groups at the beginning help the analyst to identify the most descriptive criteria for clustering. Second, as the method proceeds by merging groups into major groups that still have sufficiently similar daily mobility characteristics, both the number of criteria and mobility groups are gradually reduced, resulting in a limited number of segments as well as criteria. Earlier methods developed for this kind of clustering have been much more complex and not as easy to carry out. Due to the demographic data, the categorisation can be forecasted also to a point of time in the future.

In the case of freight transport, we used an approach called "generic logistics concept". This comprises three vertical business activities or levels: management, operations and instruments. The aim of the logistics concept was primarily to help in identifying different transport chains or operational models within a certain geographical area. Secondly, it considered different actors and their needs and preferences for the transport system and logistics services within the transport chains' three levels presented above. As a result, from six to eleven user segments were identified. National transport as well as goods transport statistics were used here as the empirical material.

The approach in Paper II contributes mainly to research question 2 by suggesting that in developing policies or technologies, the end-user preferences are critical from the points of view of policy implementation and technology acceptance and usability. The findings of paper II illustrate that a basic, system-based framework for identifying user preferences as a basis for end-user-oriented transport system and policy design could be initiated by the segmentation approach.

In Paper III, the potential of a target analysis method in acting as a link between policy objectives, targets, measures and their implementation in order to improve the policy process was illustrated. The empirical data stems from Finnish policy documents and from discussions with civil servants within the transport sector. The policy process frameworks for bounded rationality and experiential incrementalism (Birkland 2001, Talvitie 2006, Khisty and Arslan 2005) have been used as a basis for exploration and complemented with the new target analysis. The analysis has the following five steps: First, relevant policy targets and meas-

ures to meet them are screened from the policy documents. Second, a framework assessing the forms and types of interactions between targets according to six characteristics is presented. Third, the dependence of the targets is defined. Fourth, the acceptability of the policy measures presented for meeting the targets is assessed by approaching potential stakeholders about their views on the policy measures and their implementation. Finally, the expected outcomes of the policy measures are assessed against the targets identified in the first step of the analysis.

The importance of linking policy targets to implementation highlighted in Paper III relates to the general question of relating facts to values, which has been identified as one of the most important and long-standing discussions in the modern social sciences. Massive amounts of empirical data have been collected, but systematic methods for exploring the normative frameworks that give these data meaning are lacking. Marsden & Bonsall (2006), for example, refer to the issue in the transport sector by arguing that transport policy targets often do not reflect the totality of the issues. Much data has been collected on e.g. the indicators of a sustainable transport system, but frameworks on how to use these data to measure the development of transport systems in a more sustainable direction are missing. Accelerated changes in our living and working environments, with overwhelming amounts of information, are unfortunately not alleviating the process.

The approach in Paper III contributes to research questions 2 and 3 by suggesting that it is possible to appraise the potential success of transport policy implementation by studying synergies and conflicts as well as other dependencies between the targets presented in policy statements. In addition, in order to meet the targets, examination is needed of possible support for or opposition to the policy measures to reach the targets by main stakeholder groups. The target analysis method helps improve policy processes by covering all five categories of the bounded rationality concept, and consequently incorporating new knowledge into it regarding the problems, causes, consequences, stakeholders, etc. that are emerging and changing within the transport system.

Finally, Paper IV presents a generic fitness-for-purpose assessment (FFPA) method for research projects in support of transport policy. The approach aims to illustrate how to systematically analyse the usability of the information produced in research projects concerning impact and policy assessments, as well as how to build interacting networks around the assessments to support the use of policy-relevant research knowledge in practice. In addition, the paper presents recommendations on how to promote the use of the new research knowledge in the development of transport policy.

Paper IV highlights the ideas of policy networking which have gained strength recently both in European policy science and governance (e.g. Kickert et al. 1997, Marsh 1998, Peterson 2003). Also, the literature from theoretical fields of FFPA and Policy and Impact assessment has been used as a starting point for methodological development. The FFPA method was developed and applied within the framework of the Transforum Coordination Action -project within the European 6th Research Framework Programme (FP). Transforum facilitated networking and dialogue among researchers, policy makers and stakeholders by establishing an innovative knowledge Forum, which acted as an assessor of the usability of results in the fields of transport indicators, transport modelling and transport policy assessment of strategic transport research. The developed method is comprised of three parts: (1) The Project Screening Process, which describes the data collection and selection concerning relevant transport policy support projects, (2) The FFP Analysis of research projects, consisting of four assessment phases and (3) The transport researcher-civil servant network building through European-wide meetings (forums).

The general challenge taken up in the approach of Paper IV was to illustrate that linking a systematic analysis of transport research projects to researcher-civil servant network building could provide tools for the FFPA of EU research projects in support of policies, and consequently bring transport research closer to policy processes. Hence, the main contribution of the approach is to research questions 2 and 3, in showing that this kind of process is relevant for and can be accepted by both the research and policy making communities.

5. Emerging forms of knowledge production

5.1 Contribution of the papers

In the following sections I explore and identify, based on the empirical research of the papers and the theoretical part of this introduction, the emerging forms of knowledge production that can serve the needs of policy development in the changing transport system context. Further, I give examples of the methods, contributing actors and networks necessary for useful knowledge production. Finally, in section 6, I present the theoretical and practical implications of the new knowledge production forms, and outline future research needs.

Based on papers I–IV, I propose that approaches broadening the perspectives of knowledge production for traditional transport planning towards forms of e.g. foresight, networking and learning, may serve well the knowledge needs of the information society's transport policies. In the information society's transport system, the emergence of new technologies and services will bring new challenges to decision makers, researchers, businesses, and other societal actors. There will be a large variety of parallel development or innovation processes going on within a larger societal context. Consequently, the roles of public and private parties in the transport system will intermingle in different ways, and new operational practices and business models will arise. There no longer exists a small group of (public) organisations (such as the ministries, modal administrations, municipalities, i.e. "the producers") solely responsible for the decision-making. Instead, a number of dynamic decision making networks, consisting of different actors having a variety of goals, are growing up around the policy items or transport system innovations needing information and knowledge for the basis of their mutual decisions.

This means that the knowledge provided to make informed transport decisions needs to include, in addition to the traditional issues, also new forms to serve the

new needs of a wider variety of societal actors. The end-users of the knowledge will be multi-actor processes where a policy item is affected at all stages of policy making and where heuristic rules and routines have a strong influence on the behaviour of different actors (see Paper IV). Clarification of the relationship between scientific knowledge, political power and different transport system stakeholders proposed by the emerging knowledge production approaches in section 3 is extremely relevant here.

The following sections present and characterise my basic arguments regarding the emerging forms of knowledge production for transport policies in the information society. The forms are an outcome of the results of the included papers as well as the practical and theoretical considerations presented in previous sections of this summary chapter. I have named the five forms as follows: Knowledge production through system-based foresight; Knowledge production through system-based evaluation; Knowledge production in networks; Knowledge production as processes of social learning and argumentation; Knowledge production as a source of renewal. The forms are evident in each of the papers and can hence be considered as their overarching elements.

5.2 The transport system context

Traditionally, transport policy and transport system development has focused largely on transport networks (roads, railways, waterways), making the policy processes very path-dependent in nature. However, as emphasised in Papers I and II, a transport system is no longer simply physical networks or just about them. A transport system, whether international, national or local, is a large technological system containing messy and complex components. It is a socio-technical network. The state of the transport system is the result of the measures and actions carried out by the producers, operators and users of the system. Basically, the ultimate purpose of the transport system is to serve the needs and expectations of the end-users, who in turn shape the system by their own behaviour and actions. The system is thus both socially constructed and society shaping.

Producing relevant knowledge that supports the development of successful transport policies within such a system thus requires constantly evolving mapping of the system's future as well as learning from its past developments, all conducted from different societal perspectives. In the complex and networked information society, various forms of foresight and evaluation knowledge, used as

complements to each other, can provide potential approaches to support the transport system and its policy developments (Papers I and IV).

5.3 Knowledge production through system-based foresight

Foresight and visioning as approaches to anticipate future developments within a wider societal context, and using this foresight knowledge as the basis for transport policy development, has not been a traditional approach for the transport sector. Anticipating the future has focused largely on analysing past trends and been based on them, forecasting the future trends of e.g. transport volumes. The emerging knowledge production approaches reviewed in section 3 emphasise, however, seeing contingency as the main societal condition and dynamic processes by which science and society continually shape, constitute and validate one another within (Jasanoff 2004, Latour 2004, Leleur 2008). In addition, the exploratory rather than predictive value of knowledge production is seen as important.

The included papers have revealed that there is a lack of visionary thinking in the transport sector – to be more precise, a lack of innovation in using different knowledge production approaches for developing new visions for the future. In the information society's complex transport system, decisions on future development cannot be based solely on analysis of the past; also wider mapping of different futures is required. Mapping the future is essential in order to stay resilient to the rapid changes in the system as well as different societal demands of the diverse transport system users and producers.

System-based foresight as a form of knowledge production is based on characteristics relating to the use of social constructions of the transport system as the basic knowledge for policy as well as technological developments. The essential issue in this context is to gain knowledge and understanding on the dynamics of end-user acceptance as the basis for technology, service or policy developments. Socio-technical foresight methods (e.g. roadmapping) can provide good premises for coping with the systemic challenges of transport policy development. In the roadmapping approach, which we present in Paper I, different transport system and service developments are explored on different levels, e.g. user needs, markets, actors, technologies and knowledge production. In addition, short, medium and long term developments are considered.

Another example is developing methods and tools for identifying the preferences and needs of the transport system end-users as the basis for policy devel-

opment. My argument here is that by developing methods for large-scale end-user segmentation (illustrated in Paper II), which lean on theories like the Large Technological Systems Theory by Hughes (1987) or the Social Construction Of Technology (SCOT) approach of Pinch & Bijker (1987), the impact of policy measures on transport system's future could be assessed in a wider context than before. In addition, the methods might be expanded further to assess also the end-user acceptance for new technologies or policies (e.g. the system level acceptance of ICT applications).

5.4 Knowledge production through system-based evaluation

In addition to foresight knowledge, successful development of policies for the transport system of the future also requires evaluation of current and past system performance, at least from the point of view of their quality, efficiency, effectiveness, and robustness as a basis for future developments. In addition, the usability of the produced knowledge from the point of view of its end-users is of high importance. These form the basic characteristics of system-based evaluation.

One very important perspective in assessing the quality of knowledge production that has received too little consideration in the past is the evaluation of the impacts and usefulness of transport research on policy making. My argument here, based on Paper IV, is that to be able to utilise the knowledge produced with different transport policy analysis methods, and learn from them, new practices are required also in the knowledge transfer processes. Examples of these are e.g. producing the right information in the right form to fit the purposes of the policy process and its different actors, and furthermore promoting learning within the policy process. These practices are currently very poor in many Finnish and European cases. Based on Paper IV, the effectiveness of transport research projects on policy development could be enhanced e.g. in the following ways: building common transport visions from the systems perspective, increasing the effectiveness of stakeholder participation within the transport research projects, presenting research outputs of policy support projects in a form that is simple and clearly communicated, mixing theoretical and practical knowledge and people within research projects to advance the output implementation and finally establishing innovation networks of researchers and civil servants.

Another example of the possibilities raised by the characteristics of system-based evaluation regards effectiveness. In traditional transport planning, the dif-

ferent phases of policy process – namely policy objectives, targets, measures and their implementation – are often integrated very loosely, particularly targets and policy implementation. One of the problems here is that specific policy targets have relationships, which may have effects on the selection of policy measures, reaching agreement on measures between different stakeholders, and further on the success of implementation of the policy measure. Currently, there seems to be a lack of methods and tools, which could evaluate the effectiveness of the complete policy process from the perspective of the transport system (including all modes and different actors). The target analysis method presented in Paper III provides an example of such a method.

5.5 Knowledge production in networks

Referring to Gibbons et al. (1994) and Nowotny et al. (2001), I can argue that within the information society's transport system, we are experiencing the emergence of socially distributed knowledge production. It means that knowledge is both supplied and distributed to individuals and groups across the social spectrum. Here numerous different networks are emerging, and communications within and between the networks are crucial. Consequently, the knowledge will need to be produced beyond any single discipline or organisation. Here persons or organisations having the ability to work as knowledge integrators between different sources of information are highly valued. Also the co-production theorists (e.g. Hunt & Shackley 1999, Lemos & Morehouse 2005) see that "usable science" is co-produced iteratively in the context of everyday interaction between scientists, policy makers and the public.

The case studies in the included papers contribute to the above arguments and have revealed that in the information society's transport system, the methodological development regarding the emergence and evolution of new policy-relevant knowledge-production networks is of great importance. There are numerous and altering possibilities of how the networks might be built up. Here, it is important to note that the end-users of the transport system itself and the end-users of policy-relevant knowledge are often different (groups of) individuals and organisations. In some cases, individuals may even have several roles, because almost everybody can be considered a transport system end-user. The fast pace of transport-related technological development will further intensify this differentiation. It will also require building many new stakeholder and policy networks around new technology or service concepts. Different actor clusters or networks naturally

need different kinds of knowledge as the basis for their decisions. Some of it they may be able to produce themselves, some of it not.

Based on the above discussion, I propose that knowledge production in networks includes at least the following two characteristics: (1) multiple forms and levels of networks, (2) the ability to serve other forms of knowledge production, e.g. future mapping, determining quality or effectiveness and mutual learning. In the following section, I present some examples of the characteristics based on the results of the included papers.

One example is a network built around future evolvement of the transport system and visioning relating to e.g. technical development (i.e. transport system technology services within a wider societal context, Paper I). In such cases, once the new (information) technologies – such as flexible mobile interfaces, sensor technologies and real-time monitoring systems – become the basis of the transport system, the views of system itself, its actors and networks between public and private stakeholders should be re-thought. Consequently, the networks and other forms of knowledge production supporting system design and transport policy should evolve accordingly.

In the development of transport policy, particularly given the information society's complexity, networks of policy process stakeholders with different views are essential in order to gain their acceptance of policy targets and, even more importantly, of policy measures proposed for meeting the targets. Mutual agreement of the network is important since policy objectives and targets can usually be agreed upon, whereas concrete measures put the future into specific terms and create differences in opinion (Paper III). Ideally, of course, the potential of policy measures should be assessed against the needs of the end-users of the system in question. As discussed before, in the transport system, end-user issues are complex because almost everybody can be considered a user. However, not all feel directly involved with all parts of the system; there are some that they do not use or are unaffected by. Since the needs and preferences of the transport system end-users (individuals and companies) are seen as an increasingly important basis for future policy design, also here networks are needed. The networks producing knowledge can consist here (as illustrated in Paper II) of different end-user groups having similar mobility needs and preferences at a certain moment, but evolving over the course of time. The user groups provide an example of "socially distributed expertise" introduced by Gibbons et al. (1994).

A further example of the different knowledge production networks, mentioned briefly in the previous section, concerns policy networks. The network model of

Kickert et al. (1997) sees policy development as interaction processes in which actors exchange information about problems, preferences and means, and trade off goals and resources. Stakeholders in networks are interdependent because they cannot attain their goals by themselves but need the resources of other actors in order to do so. In Paper IV, such an asset is the experiential research knowledge produced in EC research projects for policy support. Here researcher-civil servant networks are an essential element in evaluating the usability of previous transport research – as well as accepting, elaborating on and disseminating the produced research results so they can be applied in policy processes.

5.6 Knowledge production as processes of social learning and argumentation

The role of traditional, analytical transport policy-relevant knowledge production described in section 3.2 has basically been to support the managerial "top-down" decision making and actions of the public authorities. Instructions and commands have been the outcomes of a decision-making process as opposed to emergence and autonomy. Within the information society, however, the concepts and rules of different stakeholders strongly influence each other's behaviour and hence their learning abilities. This is due to the network building discussed above, whereby stakeholders in networks are interdependent because they cannot attain their goals by themselves but need the resources of other actors in order to do so.

The emerging knowledge production approaches reviewed in section 3.5 propose that future practice should focus on their exploratory rather than predictive value. In addition, we should consider them more as aids to gaining better insight into and better understanding of problems in different stages of the policy process. Further, as Valovirta & Hjelt (2004) suggest, knowledge production can be seen as social argumentation, consisting of different discussions, comments and addresses. Here, the claims relating to the facts, values and strategies can be joined together into arguments, which again raise counter-arguments, persuasion, possible defence and critics. Consequently, the results will be communicated in the course of the participation, not through institutional channels.

Currently, there seem to be growing signs of understanding transport policy-relevant knowledge production (e.g. assessment, evaluation and foresight practices) in terms of social interaction processes. Such processes can be characterised as means in e.g. building co-operation relationships, future visions or trust between transport system actors in a wider societal context. Here, the processes

themselves can be seen as policy instruments. In the transport domain, new players and emerging knowledge production networks need to develop a common language to discuss emerging issues such as human-machine interfaces, user acceptance, business models, public-private partnerships, etc. within the transport system, traditionally developed only by the public sector.

Again, the papers included in this dissertation provide examples of knowledge production as processes of social learning and argumentation. Paper I illustrates the visioning of socio-technical development, here namely "technology services", as a mediator and possibly also intensifier of existing societal processes relating to e.g. economic, legal, privacy and security issues. Different actors within the transport system are invited to argue and learn through workshop discussions about the role of end-users, markets, technology and service developers and providers and other stakeholders, as well as knowledge required in the development of future transport system technology services.

My second example and argument, based on Paper III, considers the traditional, path-dependent, staged policy development processes, always starting from the "root". In order to be successful and effective, these processes need to be complemented, or in some cases even replaced, by approaches which can explore the successes and failures and can learn from the other phases as well as from various actors within the policy process and hence adjust.

My third example on the learning and argumentation processes regards the actual use of the produced knowledge. Currently, massive amounts of transport-related empirical data are collected and research results produced, but there is a lack of normative frameworks that give the data meaning, as well as practices and arenas (forums) for the acceptance and uptake of this information and knowledge in policy processes. Within such arenas (e.g. researcher-civil servant networks proposed in Paper IV), information on the latest results or best practices on selected themes could be shared and assessed, and collaborative learning could take place.

5.7 Knowledge production as a source of renewal – forming new identities and institutions

Within the information society's transport policy development, one of the greatest challenges will be to adjust policy developments on the one hand and end-user needs, preferences and acceptance on the other, on the rapidly advancing technological frontier. Policy makers, civil servants, commercial actors and other socie-

tal stakeholders worldwide will need to understand the kinds of changes that are occurring in society as the basis of their decisions. These changes may occur very fast and will not necessarily be visible through official statistics. This will consequently influence the required concepts of knowledge production and competencies. In order to be useful, knowledge production and competencies need to be resilient to constant change in the transport system and the surrounding society.

In the above context, by "knowledge production for transport policy as a source of renewal" I mean the need to understand the pathways by which transport policy-relevant knowledge production occurs, operates and renews the society. By further elaborating on the co-production concept by Jasanoff (2004), I have identified the following two characteristics for this form of knowledge production.

Making identities refers to the importance of understanding different roles knowledge and its production play in developing, shaping, sustaining and giving meaning to new transport policies, technologies, services or concepts and related social roles (e.g. experts, civil servants, policy makers, technology developers, transport system end-users). As technologies and services change and renew, different transport system actors, their needs, roles and behaviour, and the forms and contents of the produced knowledge need to change accordingly. In the development process, it is important to highlight the contest between the old forms and structures of knowledge production and the new ones, since building new forms without discharging the old is almost impossible. Markets, various policies and the level of co-ordination, at the very least, constitute the dimensions, which shape the mechanisms of forming new transport identities and institutions.

Currently, there is very limited amount of information available on these mechanisms in the transport context. Due to the development of the information society, the roles of different actors within knowledge production in the transport domain are currently under transition. Hence, the topic of making identities is extremely relevant. Who will be the future producers and users of knowledge relevant to transport policy: public actors, private actors, individuals or new networks or consortiums developing around transport technologies and services?

An example of making identities can be found e.g. in identifying key concepts for the future development of the transport system. In Paper I, networking technologies, real-time based interactive systems and service packaging were identified as such "technology service" concepts. Here, making identities means understanding of how to integrate different transport technologies into these service concepts, what kind of roles different transport system actors can have and what kind of knowledge they need within the development process of such technology

services. It also means discussing and identifying the different meanings technology services can bring to policy development and the different transport system stakeholders.

In Paper II, we illustrate that new identities, "personas", important for the future transport policy design could be found by categorising the transport system end-users into homogeneous segments. The needs and preferences of the "personas" could be further investigated by e.g. surveys or interviews. The adaptations and acceptance of different user segments regarding the new transport technologies and services will be of great importance in the future design processes, be it policies, technologies or services.

The other characteristic, *making institutions*, is an outgrowth of the former one and emphasises that when contexts and knowledge change, new institutions will emerge to provide a web of social and normative understanding within which new identities can be recognised and given effect. In the transport sector, where the traditional requirements for institutions have been e.g. to make laws, standardise measures and methods, ratify new identities and interpret evidence, there is currently a need to advance the understanding of the linkages between intelligent transport systems and services and society as integral to the traditional functions of institutions.

Paper IV provides an example of making institutions. In the paper, we describe fitness-for-purpose assessment of transport research projects as a source of renewal for the European research agenda, as well as for building research-policy networks. Here the network illustrates one possible new form of institutions and governance.

6. Discussion and conclusions

6.1 Scientific and practical implications

The traditional view of knowledge production supporting transport policy and planning has been very reductionist. In general, the approaches of knowledge production have aimed to reduce transport system complexity to components and elements, or even to a single number (e.g. CBA). In the information society, however, the complex, networked and adaptive nature of the transport system and policy processes is in evidence everywhere. Thus, simplifications by themselves are no longer adequate, but need wider, societal approaches as their complements. The traditional project level approaches do still have importance, especially as a part of project assessments. However, for understanding the social constructions of the transport system as the basis for knowledge production and for understanding the relationships between knowledge production, policy formulation and decision making, additional new forms are required. This concerns knowledge production for transport at all levels: local, regional, national and international.

The purpose of this dissertation is to broaden the understanding of the dynamics of knowledge production supporting transport policies of the information society. Further, the ambition is to identify what forms knowledge production supporting transport policies of the information society should have. Keeping that in mind, the first research question seeks answers to what kind of challenges and opportunities the changing transport system poses to knowledge production and contributing actors supporting transport policy development. Essentially, section 2 of this dissertation presents several answers to research question 1. In the most concise form, the answer is as follows: First, the pace of development as regards intelligent transport systems and services (ITS) and transport policies is quite dif-

ferent. The challenge is how to integrate the design of traditionally very slow transport policies and a technological frontier that is moving very quickly.

Second, mostly due to recent socio-technical developments, the number of actors within the transport system development has pluralised. Hence, the system and policy developments are shifting towards a more societal process including many, old and new, public and private actors, such as service providers, technology developers, private individuals, advertisers, lobbying organisations, legislators etc. Managing the production, processing and use of the knowledge within this context is a demanding task.

Third, relating to the second point, the information society's knowledge production is no longer serving a single public policy process. Instead, there are several different public-private development or innovation processes ongoing throughout the transport system. The end-users of the transport system can also be part of theses processes as information providers and integrators. The needs and preferences of end-users as the basis for the system and policy developments are of great importance here. The challenge is how to identify and integrate the information needs of these processes as the basis for "usable" knowledge production to serve transport policies and decisions. In this context, the exploratory rather than predictive value of knowledge production is important, as well as understanding the dynamic processes by which knowledge and the transport system continually shape, constitute and validate one another.

The second research question aims to identify what are the emerging/new forms of knowledge production that can serve the needs of policy development in the changing transport system context. Table 1 below gives the most concise answer to the question. Section 5 of this dissertation looks in detail at the contents and motivation of the various forms and their characteristics.

Table 1. Emerging forms and specifying characteristics of knowledge production for transport policies in the information society.

Form	***Characteristic***	***Derived from Paper***
Knowledge production through system-based foresight	Social constructions of the transport system as the basis for policy and technology developments	I, II
Knowledge production through system-based evaluation	Quality, efficiency, effectiveness and robustness of system performance as the evaluation criteria	III, IV
	Usability of the produced knowledge	
Knowledge production in networks	Multiple forms and levels of networks	I, II, III, IV
	Ability of networks to serve other forms of knowledge production	
Knowledge production as a process of social learning and argumentation	Building co-operation relationships, future visions or trust between transport system actors in a wider societal context	I, III, IV
	Processes as policy instruments	
Knowledge production as a source of renewal	Making identities	I, II,III,IV
	Making institutions	

The five forms of knowledge production, along with the examples in the included papers provide an inroad to understanding the emerging perspectives I consider important for designing transport policies in the information society. The forms are complementary, which means that they will strengthen one another when appearing simultaneously.

The third research question explores what are the scientific and practical implications of the emerging knowledge production forms. The scientific implications of the dissertation are twofold: First, the dissertation aims to open up the discussion on new forms of knowledge needed to support transport policy development in the information society. As discussed in section 3, traditional transport planning methods have strong technological and institutional bases and hence wider, more societal approaches are lacking. The emerging forms of knowledge production identified in this dissertation, based on emerging knowledge production practices in the field of STS, provide a starting point to wider discussions and methodological development in the systemic, socio-technical transport context.

Second, the knowledge production methods developed in the included papers widen the methodological base of knowledge production in support of transport policies. The methods illustrate new, communicative tools to support policy development of a complex socio-technical transport system. They do not aim to replace traditional transport planning methods but to complement them. For example, Papers I and II highlight the need to find tools or methodologies revealing interactions between technology and end-user needs and acceptance i.e. to move on from developing technologies to understanding the meanings of the results to the end-users. They also emphasise the need to understand different kinds of uses for different kinds of technologies and services.

The main practical implication of the dissertation is the development of new, concrete tools (in the included articles) for the use of transport policy design and decision-making processes. The tools are suitable for use by various kinds of stakeholders within the policy and research and technology development processes. In addition, the emerging forms aim to structure knowledge production in any systemic, strategic decision-making process – public, private, or a combination of both. Hence, the new forms support the often technical and institutionalised knowledge production relating to the substance (transport infrastructure) issues. For example, fitness-for-purpose assessment, presented in Paper IV, enables formulation of the recommendations and best practices based on the mutually agreed results, as well as shaping the future policy agendas collectively by all participating parties. This kind of process improves the usefulness of the produced results, strengthens the commitment to apply the recommendations in future activities, and urges different parties to work together in future policy activities. Currently, in the transport policy – ITS context, the problem is that still too few forums exist for networking, interaction and knowledge dissemination.

Knowledge production for transport policies is a topic the relevance of which, both in scientific and practical terms (see sections 1 and 2), has been questioned in Finland for decades. At the European level, the issue has been considered more important, at least in the context of the European Commission's Framework Program research projects. In both of the above contexts, rational transport planning as a form of knowledge production has received sporadic criticism since the 1950s (e.g. Leleur 2008, Pill 1978, Paper III). One may therefore ask what the ITS development brings to the discussion that is new. To my understanding, the challenges presented as the main results in answer to research question 1 at the beginning of this section provide the answer to the question. The systemic nature and complexity of the transport system and its different actors do propose new re-

quirements for knowledge production. Consequently, I consider the identification of emerging forms of knowledge production and the concrete methods supporting the framework, developed in the included papers, as the main scientific contributions of this work. Further, returning to the co-production approach (see section 3); the dissertation contributes to the usability of the produced knowledge. The identified forms together with the methods in the included papers strengthen the scientific base of knowledge production for transport policies and provide practical guidelines on how knowledge can be gathered and used within the development of transport policy in the information society.

The identified forms are generic in their nature. This means that they can be applied to different levels of the transport system and policy development. In addition, they can be transferred to other fields of society where policy, technology and services need to be developed in collaboration.

6.2 Future research needs

Based on the theoretical part of this dissertation and the included papers, the most important future research needs regarding knowledge production for transport policies in the information society are as follows.

I propose that in the future, development of the transport system and policies needs to be based more on continuous systemic foresight as well as ex-ante and ex-post assessments regarding system performance. It is important that indicators presenting the results of such assessment could focus on the quality (based on end-user views), efficiency, effectiveness, and robustness of the system, not its individual parts. Development of approaches identifying the impacts of transport strategies and policies on the quality of people's daily mobility and companies' transportation of goods are very relevant here. Examples of such approaches are user-centric design in general and societal impact assessments and indicators. From the technology side, new demand analyses of technology services, market foresight and public-private business model development are important fields of research. Large enough national research and development programmes, as well as technology service pilots financed by both the public and private parties could serve as a possible means for developing knowledge production in the above themes.

Second, there is a need to develop tools to gain understanding of the different forms that knowledge and its production can take in shaping and sustaining the social roles of different transport system actors or giving them power. For exam-

ple, the meaningful use of new transport technology services is grounded in social groups within which technological change appears. In order to assess the influence of new technologies on the transport system, both the public and private stakeholders in the development process need first to identify the different user groups, within which the change could appear. Only then do they have the possibility to continue further, into identification of their preferences and acceptance for intelligent technologies.

Third, network management is the key research need in the information society's transport system. Networks are often quite easy to build but very hard to manage. This holds true especially for lasting public-private partnership networks in technology service development and maintenance. There is a need to develop strategic level policy processes as interaction processes in which actors exchange information about problems, preferences and means, and trade off goals and resources. Referring to Klijn (1997), actors in policy networks are interdependent because they cannot attain their goals by themselves, but need the resources of other actors to do so. Another important research need regarding the networks is how they can learn to gain societal influence that is crucial for the legitimacy or implementation of policies.

Fourth, focusing on the usability of the produced knowledge from the point of view of its end-users (policy, business, research or individuals) is essential in an information society where the creation, distribution, diffusion, uses, integration and manipulation of information is a significant economic, political, and cultural activity. The main research needs in this field relate to the identification of emergent characteristics and the development of processes of communicating knowledge, both scientific and practical, in the course of the participation, not through institutional channels. For example, to be accepted and effectively applied by practitioners and decision-makers, the capabilities of the developed scientific research knowledge need to be checked against factors like transparency, inclusiveness, but first against acceptability and appropriateness in terms of the needs of the final users in policy and business. Currently, the processes for facilitating this check and meanwhile communicating the knowledge to the wider audience of transport system practitioners are missing.

Fifth, when contexts and knowledge change, future research is needed to help in understanding how and what kind of new institutions will emerge to provide the web of understanding within which the new knowledge can be recognised and given influence. In many European countries, including Finland, there currently exist open forums (e.g. ITS Finland) for the cooperation of companies, public

administrations and telematics developers to promote the deployment of concrete ITS services for private and corporate users. The role of these emerging institutions has been strong in pushing the new transport technologies and services onto the market in short term, but the role in advancing the understanding of the linkages between technology and society has been modest. That is e.g. in understanding how to build long-lasting public/private business models for transport technology services or how technology changes the behaviour of the transport system's end-users. Future research is needed to probe the institutional developments regarding these fundamental issues.

Finally, the ideas of the emerging knowledge production forms identified in this dissertation for transport policies in the information society have to be further elaborated and put into more concrete terms from the points of view of different transport system and policy stakeholders. The list of forms is in no sense exhaustive. To my understanding, it will evolve constantly, and keeping up with its changes is challenging. I hope, however, that the forms can speak to the realities of civil servants and policy makers, business managers, researchers and the public within the information society's transport domain at both national and international levels. I believe that they can shed light on the relationships between knowledge production, policy making, and society by e.g. facilitating network discussions and mutual learning. Such discussions and learning can create new options for the future, experimenting with different solutions to problems, and implementing new, socially embedded ways of developing transport systems and policies.

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Title

Knowledge production for transport policies in the information society

Abstract

The dissertation explores and analyses the challenges and needs that developments in the information society are bringing to knowledge production supporting policy development and strategic decision making in the field of transport. Currently, the context of transport policies is about to shift from a transport infrastructure network design towards the development of a large socio-technical system, depending largely on ICT technology and applications. In this new context the traditional, analytical knowledge production approaches relating to infrastructure investments and project appraisals are alone not sufficient in providing the knowledge needed to understand the socio-technical nature of the transport system. The knowledge provided to make informed transport decisions needs to include also new forms to serve the needs of a wider variety of societal actors. Based on the fields of science and technology studies (STS) and policy and impact analysis the dissertation presents five emerging forms relevant to transport policy knowledge production in the future. These are knowledge production through system-based foresight, knowledge production through system-based evaluation, knowledge production in networks, knowledge production as processes of social learning and argumentation, and knowledge production as a source of renewal. Further, the basic characteristics of these forms have been identified. The dissertation proposes that the presented forms can shed light on the relationships between knowledge production, policy making and the society, which may lead to the implementation of new, socially embedded ways of developing transport systems and policies. Also implications of these emerging knowledge production forms for transport policy and business development and related future research needs are presented.

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Tekijä(t)
Anu Tuominen

Nimeke

Tietoyhteiskunnan tiedontuotannon käytännöt liikennepolitiikan valmistelussa ja strategisessa päätöksenteossa

Tiivistelmä

Väitöskirja tarkastelee tietoyhteiskuntakehityksen mukanaan tuomia muutostarpeita, jotka koskevat liikennepolitiikkaa, liikennejärjestelmien kehittämistä ja näihin liittyvää strategista päätöksentekoa palvelevaa tiedontuotantoa. Liikennejärjestelmä on murroksessa – se on muuttumassa vähitellen kohti kommunikoivaa systeemiä. Kommunikaatiota ja tiedonsiirtoa tulee tapahtumaan liikennejärjestelmän eri osien, käyttäjien (ihmisten ja yritysten), kulkuneuvojen ja infrastruktuurin, välillä kaikkiin suuntiin. Myös julkisten ja yksityisten toimijoiden roolit liikennejärjestelmän kehittämisessä muuttuvat ja sekoittuvat. Liikennepolitiikan valmistelun ja strategisen päätöksenteon apuvälineiksi tarvitaan perinteisten vaikutusarviointien lisäksi uudenlaisia toimintamalleja ja käytännön työkaluja, jotka pystyvät ottamaan huomioon entistä paremmin liikennejärjestelmän sosioteknisen luonteen ja muuttuneen toimijakentän. Väitöskirjan teoreettinen viitekehys koostuu pääosin tieteen ja teknologian tutkimuksen esille nostamista uusista tiedontuotannon käytännöistä ja teorioista, jotka pyrkivät ilmentämään tieteen, teknologian ja poliittisen vallan välisiä suhteita yhteiskunnallisessa päätöksenteossa. Työssä sivutaan myös perinteisiä liikenteen vaikutusarvioinnin ja politiikka-analyysin tieteenaloja. Väitöskirja esittää viisi tietoyhteiskunnan liikennejärjestelmää palvelevaa tiedontuotannon muotoa ja näitä kuvaavat keskeiset piirteet, jotka on tunnistettu relevanteiksi tiedontuotannon ulottuvuuksiksi teoreettisten viitekehysten ja neljän tapaustutkimuksen avulla. Nämä viisi muotoa ovat tiedontuotanto järjestelmätason ennakointitoiminnan avulla, tiedontuotanto järjestelmätason arviointitoiminnan avulla, tiedontuotanto verkostoissa, tiedontuotanto oppimis- ja argumentointiprosessina sekä tiedontuotanto järjestelmän uudistajana. Väitöskirjassa esitetään lisäksi päätelmiä tunnistettujen tiedontuotannon muotojen politiikkaseuraamuksista ja jatkotutkimustarpeista.

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