Situations of Opportunity for Infrasystems

Understanding and pursuing change towards environmental sustainability

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Abstract

Infrasystems are the large technical systems in society delivering water and electricity, making communications and transports possible, managing the gathering and treatment of refuse and sewage, and many other services. Infrasystems mean welfare, convenience and economic growth, but also considerable environmental impacts.

The overall aim of this thesis is to contribute to the development of aspects and prerequisites of infrasystem change in a sustainable direction, by way of elaborating conceptual knowledge. The first main point of departure is the concept of *infrasystem*, and the related approach *Large Technical Systems* (LTS), primarily associated the field of history of technology. A key feature is to highlight a *socio-technical systems perspective*, rather than separating technology from social and institutional aspects.

The second main point of departure is the change perspective *Situations of Opportunity* (SITOP), which is a draft theory developed within a research programme at the Royal Institute of Technology. SITOP set out from the notion that the possibility to implement changes in a sustainable direction is greater than average at certain moments in time. A situation of opportunity is associated with a *prehistory*, limiting the *field of options* for the actors utilising a *formative moment*.

When SITOP, LTS and other related socio-technical perspectives are cross-fertilised some directions of where to look for *future situations of opportunity* for infrasystem change in a sustainable direction can be pointed out, e.g. in connection with certain problems or crises in the systems' development. On the one hand different aspects on how to *widen the field of options* are discussed, e.g. to promote inter-sectorial actor networks, to identify system synergies and social innovations (paper 1-3), and to highlight services and functions rather than sectors and technology (paper 2). On the other hand, in order to approach the great changes needed in the context of sustainable development, the *socio-technical regimes* of today have to undergo major alterations, which probably presupposes new sets of actors and actor networks. A more moderate view however, is to seek positive synergies between everyday

decision- and policy-making and the long-term striving for sustainable development. Issues often considered as necessities, e.g. renovations of old buildings, or building more roads to moderate congestion – 'what must be done' – should be combined with 'what should be done', e.g. implementing energy saving solutions in the built environment, or reducing society's transport dependency. The array of conceivable combinations *widens the field of options*.

The results also concern indirect effects of infrasystems, which might contribute to processes *evaluating fields of options*. Infrastructure investments affect activity patterns and the built environment (paper 4). Moreover infrasystems are associated with indirect energy use (paper 5).

The conceptual views presented in this thesis are no immediate means, ready to be used in concrete infrasystem management, but can in the steps that follow primary policy-making support the process of finding out when to implement change, and moreover assessing plausible solutions. In other words – *identify situations of opportunity* and *explore the field of options*.

Preface

Any image of thought dealing with how technology, society and the environment affect one another is complex, variable and associated with uncertainty. This is also the case when my organisational affiliations during the years of which this thesis has evolved are considered. During 1998-2000 I belonged to the Environmental Strategies Research Group (fms), which was a joint venture between the Department of Systems Ecology at Stockholm University (where I was employed at the time), and the Division of Defence Analysis at the National Defence Research Establishment (FOA). During 2001, I took a break from research and wandered about as a consultant in the remains of the collapsed IT sector. When I returned to environmental research and the fms group in 2002, FOA had transformed into FOI – Swedish Defence Research Agency. FOI became my new employer. In late 2003, the fms group was divided into the Centre for Environmental Strategies Research at the Department of Infrastructure at KTH, and the Department of Environmental Strategies at FOI. Since then both FOI and KTH have been reorganised. The centre at KTH has become the Division of Environmental Strategies Research at the Department of Urban Planning and the Environment at the School of Architecture and the Built Environment, and the department at FOI has become the R&D Group for Energy and Environmental Security within the Division of Defence Analysis. Apart from my doctoral project, I have during this period of time been working in other projects both at KTH and at FOI separately, but also in joint projects. Anyhow, my doctoral project at KTH was affiliated at the Division of Built Environment Analysis (also at the Dep. of Urban Planning and the Environment), but when the division was closed down, I changed my specialisation to Environmental Strategies Analysis.

OK, to sum up, today I am a Senior Scientist at the Division of Defence Analysis at FOI, oriented towards Energy and Environmental Security, and an Associated Researcher at the Division of Environmental Strategies Research at KTH.

This doctoral project was funded by The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas). However, since some of the papers attached to this thesis, to various extents, are spin-offs from other projects, credits should also go to the Swedish Environmental Protection Agency (Naturvårdsverket), the Swedish Governmental Agency for Innovation Systems (Vinnova), the Swedish Energy Agency (Energimyndigheten), and the Ministry of Defence (Försvarsdepartementet). Besides, FOI has funded some extra time needed for the final preparation of the cover essay.

Many people have supported me during the years of which this thesis has evolved. First of all, the late Peter Steen who took me in at fms and encouraged me when I frequently fell into the typical pitfalls of junior researchers. Peter did however not pay much attention to academic merits – more important was to produce interesting and relevant research, and that conventional truths always should be challenged. I hope that at least a fraction of the spirit of Peter's work can be traced in this thesis.

Arne Kaijser introduced me to the infrasystem concept and was of course indispensable in the process of writing *Infrasystemens dynamik* (Jonsson et al. 2000). Arne has always been available for discussing new research ideas and to comment on my papers. I am especially grateful for the comments on this cover essay on my final seminar, where Arne had the role as main discussant. Together with Anders Gullberg, Arne persuaded me to consider writing a doctoral thesis. From start, Anders has supported this project, for which I am grateful. Anders also formulated (in Jonsson et al. 2000) the conclusions used as main points of departure in paper 1-3 of this thesis. Anders was also the one who introduced me to Örjan Svane, who became my supervisor at KTH.

Örjan has been more helpful and flexible than one can expect. He got me the necessary funding. He provided me with an interesting theoretical approach and when I wanted to use it on infrasystems, Örjan simply reformulated the project. I sometimes feel like I got this project served on a silver platter, alternatively that I hijacked Örjan's project. During the period of being a student once again, Örjan allowed me to maintain my integrity and to explore in an independent manner. I am much grateful and I have certainly enjoyed our creative discussions.

Örjan also played an important role when additional funding was raised, necessary to finalise this thesis. In that context, I also wish to acknowledge the efforts of Annika Carlsson-Kanyama and Jan Erik Rendahl at FOI. Thank you for your support. I also appreciate the support of Göran Finnveden, in terms of fixing me a temporary employment at KTH, and for useful comments on drafts of the cover essay. Moreover, I have enjoyed working together with Göran in projects not directly related to my doctoral activities. And since this thesis bears traces from a lot of other projects, there are many colleagues and co-writers who have crossed my path during the last eight years to whom I am grateful. I will not mention all of them, however, Karl Henrik Dreborg is more than a colleague – he brought me back to environmental research in 2002 and is a great mentor. Jonas Åkerman has taught me at least half of what I know about the mechanisms behind transports and energy use. A great deal of the rest should probably Mattias Höjer and Greger Henriksson have credit for. I have really been enjoying our transport future studies, also including a number of other past and present researchers from fms and Stockholm Environment Institute (SEI).

I appreciate the elaborations on the change perspective used in this thesis, by my fellow postgraduate students Carina Weingaretner-Kohlscheen and Susanna Elfors (now Ph.D.). I am also grateful to Åsa Sundkvist, for letting me share her room at KTH, and Rebecka Engström, for tactical insights considering both science and administration, and Leif Hedberg, for constantly feeding me with new music. The excellent library services of Gunnel Olofsson at SEI and Berit Forsberg at FOI should also be acknowledged. Thank you.

Finally, I owe a lot to Jessica Johansson. Jessica, the uncrowned queen of morning weariness, is not only the co-writer of paper 4 of this thesis and a much appreciated colleague and friend. She is also one of the sharpest minds I have met. I also honour the intelligent insights, and the unconditional support and patience of my favourite sounding board Cecilia. Our kitchen table (i.e. my writing-desk) has rather been exposed to unsorted papers, book piles and ‘to do’-notes than food lately. I will do the same for you, my love, when you finally decide to become a doctor... ;-)

The past fms group in old town Stockholm was characterised by commitment and creativity, and not the least, by independency and integrity. Thank you all for a great start in my working life. The new affiliations at FOI and KTH have opened up for new opportunities in terms of merits and careers, but above all, for new research areas and co-operations, and for new arenas to pursue change in a sustainable direction. Let’s explore these situations.

In spite of the fact that the lonely work of writing a doctoral thesis is demanding in many ways, I have managed to squeeze in some leisure time now and then, which primarily has been used to restore an abandoned cottage on a lakeside in Hälsingland – a small timbered house with no modern conveniences. Compared with writing a thesis, this project has stimulated creativity and problem solving of a completely different nature, which has been a great relief. Besides, I find it really refreshing to sweat and to get wood splinters in my hands. Anyhow, now the roof is fixed, the floor is stable, and I think the walls might stand. However, an issue that has been under way lately, is how I will fulfil my need for water, heating, hygiene, lightning, food preparing, communication etc? I would say it is time to invite some infrasystems. This is a situation of opportunity in miniature – an important decision-making moment that will influence the functions and appearance of my house for many years to come. I want to select solutions with good long-term quality and economy, and of course, I will not let the arrangements threaten the precious birds, flowers and threes on my little piece of land, nor the water and the tasty fishes in the nearby lake. Moreover, the infrasystems will not only connect my little paradise to the rest of the world with wires, pipes and cables – they will also link to immediate and future, global environmental effects. My house will become yet another low-level node interfacing the networks of infrasystems – the socio-technical arrangements associated with welfare, growth and the conveniences of modern life-style, but also with complex institutional and technical set-ups, legal and economical conditions, profit interest, politics, and long-term effects on society, human health and the environment.

For me, in my little corner of the world, it is time to decide. No matter how I choose, I'm sure my grandchildren will scrutinise my choices – in a local, as well as in a global context.

Daniel K. Jonsson

Kungsholmen, Stockholm, October 2006

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1. Introduction

The concept of *sustainable development* summarises the challenges that the world is facing – to manage a global social and economic development, which neither degrades the ecological systems nor exhausts natural resources. Infrastructure systems, hereafter referred to as infrasystems, play a key role in this problem area. The development of infrasystems has in many ways made everyday life easier. Infrasystems supply clean water, energy for heating and illumination, Internet access, telephone services, transport of people and goods, gathering and treatment of refuse and sewage, and a number of other services. They are the large technical systems in society, supplying, distributing and delivering specialised services, materials and assets to households, companies and organisations.

The concept of *infrasystem* was developed by Arne Kaijser (1994), a Swedish historian of technology. According to Kaijser's definition, infrasystems are large technical systems with a public character – they should be accessible for all potential users within the geographical area covered by the system. Kaijser divides infrasystems into the categories; transports (of people and goods), water and sewage, energy, waste, and communication (of information). From a technical point of view Kaijser describes infrasystems as networks of links and nodes housing certain flows. From an all-embracing perspective however, Kaijser points out that infrasystems should be treated as socio-technical systems – they should also be associated with the people, organisations, and authorities that plan, build, operate, use, and regulate the systems, and the economic and legal conditions for the activities (Kaijser et al. 1991; Kaijser 1994). Accordingly, the development of infrasystems should be regarded as socio-technical processes of change – described by Kaijser through three different phases of infrasystem development: the establishing, expansion and stagnation phases.

The expansion of infrasystems has been of great significance for the development of industrialised society since the beginning of the 19^{th} Century. However, modern society has its problems in terms of substantial environmental impacts. The development of infrasystems in the Western World is one important contributory factor to this dilemma since it has become so easy to use the services provided by the systems. Infrasystems contribute to the environmental burden through the way they function and reinforce a societal development that often takes for granted high levels of consumption, long journeys and intensive energy use. Moreover, the negative effects are often distanced from the consumer,s due to the large-scale nature of the systems.

Infrasystem services in the Western World can in most cases be labeled with all of the three characteristics: cheap, convenient, and reliable. This means that the problematic qualities of the infrasystems, seen from an environmental and resource-consumption perspective, are intimately connected to their advantages, which naturally implies that changing infrasystems in a sustainable direction is a great challenge.[1]

The infrasystem concept, and reflections upon sustainable development, are further elaborated in chapter 2. Below follows the specific aim and scope of this thesis, a discussion of the relation between the cover essay and the papers, and also a brief discussion over what fields of research, or academic disciplines, this thesis could be associated with.

1.1 Aim and scope

This thesis explores how *infrasystems* can be *changed* in the context of *sustainable development*. The overall aim is to create new conceptual knowledge about infrasystem change, and to contribute to the theoretical development of the change perspective used.

Infrasystems are not only sets of technical components. An infrasystem – as an object of change – should, as described above, also be associated with the people, organisations, and authorities that plan, build, operate, use, and regulate the systems, and the economic and legal conditions for the activities. The socio-technical systems perspective is a fruitful way to understand these circumstances, which often is manifested through the *Large Technical Systems* approach (LTS) (e.g. Hughes 1983

[1] The introductory section in this chapter is at large the same as the introduction in paper 2.

and 1987; Summerton 1994; Kaijser 1994). In order to understand infrasystems as socio-technical systems the LTS approach is used in this cover essay.

Various change perspectives, or approaches, can be used when addressing certain processes of change. The change perspective I have chosen to use and elaborate in this thesis is the concept of *Situations of Opportunity* (SITOP) (Svane 2005a and 2006; Weingaertner 2005), promoting the view that the possibility to implement socio-technical changes, in order to gain environmental improvements, is greater than average at certain moments in time.

While the LTS approach is an established research tradition, the SITOP approach might be considered a draft theory, or a research strategy 'under construction', which is elaborated in a research programme involving researchers from several institutions, mainly at the Royal Institute of Technology in Stockholm. The research theme includes a number of case studies and theory and method development projects – of which this cover essay is one example.

In this thesis, the SITOP approach is used in order to explore how infrasystems can be changed in the context of sustainable development. Moreover, the aim is also to contribute to the theoretical and methodological development of SITOP.

Roughly speaking, the historically oriented LTS approach describes and explains *how change has taken place*, or if making a broader interpretation, *how change can take place*, while the overall purpose of the SITOP approach is to support the process of *how to change*. The LTS approach (including other related socio-technical approaches) and the SITOP approach are elaborated in the theory sections (chapter 2), in order to outline a synthesis combining the different theoretical approaches (chapter 3). Common features, differences and synergies are discussed. Some directions of where to find situations of opportunity for infrasystem change – aiming for environmental sustainability – is pointed out. Moreover, the actor perspectives of the combined approaches are discussed at different levels.

The papers attached to this thesis were written independently of this cover essay (see section 1.3, for the original aims and purposes of the papers). In spite of that fact, the papers constitute an important part of this thesis taken together. In chapter 4, reflections on the papers are made in relation to the elaborated approaches and the synthesis of chapter 3. In essence, this procedure can be described as a re-review of the papers using goggles filtered by the synthesis. Conclusively, the synthesis is supplemented in the concluding discussion of chapter 5, based on findings from chapter 4.

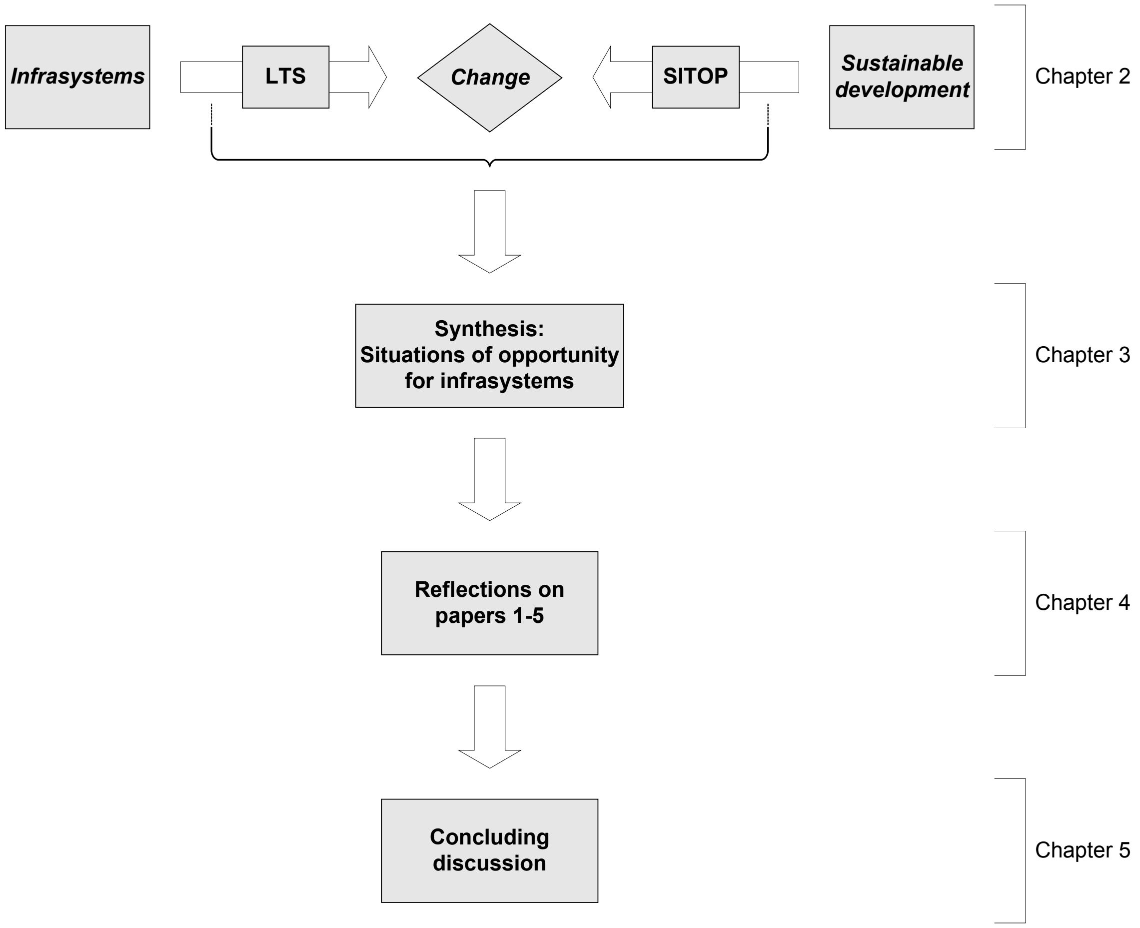

Figure 1. Illustration of the approach and contents of the cover essay. The theme 'infrasystem change in a sustainable direction' is explored by way of combining LTS and other related socio-technical concepts with the SITOP approach, which is goal-oriented towards sustainability. The synthesis is applied on papers 1-5, resulting in the conclusions of this thesis.

1.2 The relation between the cover essay and the papers

As mentioned above, the papers attached to this thesis were written independently of the cover essay. One of the key concepts in the cover essay – the SITOP approach –

is not used in any of the papers. So, there is an obvious discrepancy between the cover essay and the papers. However, the role of the papers attached to this thesis is more than just to account for a couple of scientific publications. The ambition in this thesis taken together goes beyond the themes in the papers, hence the insights and perspectives elaborated in the cover essay is used to re-review the papers, and do what was not the immediate interest when the papers originally were written.

A doctoral thesis could either be a monograph over the topic of concern, or a compiled thesis based on scientific papers and a cover essay. There are however several interpretations and opinions of the role of a cover essay in a doctoral thesis. In a typical cover essay (from my point of view), the theoretical background is accounted for, the papers are summarised, and some generalised knowledge extracted from the papers is elaborated. A more stringent view is that the thesis equals the published papers, i.e. there should not be any new knowledge in the cover essay, only a summary linking the papers. On the other hand, the opinion that the cover essay is the actual thesis, with the papers as less important attachments, is not unusual (which approaches the monograph concept). In this thesis the cover essay is important but the papers are more than just attachments. The papers could be seen as one independent part of the thesis, and chapter 2-3 of the cover essay could be seen as another (theoretically oriented) independent part. The mutual benefits sprung out of the different parts are gathered and discussed in chapter 4-5.

Each paper is briefly summarised in section 4.1-4.5, in relation to the synthesis in general and the SITOP concept in particular. However, the prehistory of the papers is described in the following section.

1.3 The papers attached to this thesis – a brief research history

The papers attached to this thesis are:

Paper 1	Jonsson, D. (2000), "Sustainable Infrasystem Synergies: A Conceptual Framework", *Journal of Urban Technology*, vol. 7, no. 3, pp. 81-104.

Paper 2 Jonsson, D. K. (2005), "The Nature of Infrasystem Services", *Journal of Infrastructure Systems*, vol. 11, Issue 1, pp. 2-8.

Paper 3 Jonsson, D. (2004a), "Integrating Urban Infrastructures of Movement: A Vision of Sustainability", pp. 211-223 in Hanley, R. (ed.): *Moving People, Goods, and Information in the Twenty-First Century: The Cutting-Edge Infrastructures of Networked Cities*. Routledge, New York.

Paper 4 Jonsson, D. K., and Johansson, J. (2006), "Indirect effects to include in Strategic Environmental Assessments of transport infrastructure investments", *Transport Reviews*, vol. 26, no. 2, pp. 151-166.

Paper 5 Jonsson, D. K. "Indirect energy associated with Swedish road transports", submitted to *European Journal of Transport and Infrastructure Research*.

Independently of this thesis, the purpose of paper 1 is to contribute to the conceptualisation of infrasystem characteristics, and to discuss synergies as a means of steering infrasystems onto sustainable paths. The change perspective elaborated in paper 2, is social innovations in relation to a structural approach to understand infrasystem services via the underlying needs, utilities and conveniences. The purpose of paper 3 (partly based on paper 1) is to elaborate on some alternative urban transport solutions. The aim of paper 4 is to contribute to the methodological development of how to assess transport infrastructure investments, by way of addressing indirect effects. Paper 5 shows the results of a quantitative study over energy use in the Swedish road transport sector. The aim of paper 5 is to highlight the significance of indirect energy.

Paper 1, 2 and 4 have been published in scientific journals. Paper 4 was written together with Jessica Johansson. The article was written in a manner of close co-operation and we both have contributed to its entirety, however I was essentially responsible for the parts discussing the indirect effects, while Johansson should have the main credit for the concluding discussion concerning using scenarios in transport planning. Paper 3 was published as a book chapter in an anthology. Paper 5 has been submitted to a transport-oriented journal but is not yet accepted for publication.

The papers attached to this thesis summarise some of the findings and theoretical proceedings developed through my research activities during 1998 – 2006. Those activities generally resulted in research reports in Swedish – see detailed list of publications in the reference section.

The report Jonsson et al. 2000: *Infrasystemens dynamik – om sociotekniska förändringsprocesser och hållbar utveckling* (translation: *Dynamics of the infrasystems – socio-technical processes of change and sustainable development*), written together with Anders Gullberg, Arne Kaijser, Marie Jungmar, and Peter Steen, was the result of a multidisciplinary research programme, which can be identified as the one of main points of departure of the research theme elaborated in this thesis. Especially the conceptualisation of infrasystem characteristics and the explorations of the conditions of change for infrasystems, presented in papers 1 – 2 (to some extent also paper 3), emanate from findings in Jonsson et al. 2000. Also my basic socio-technical outlook – elaborated in this cover essay – has its roots in the work with Jonsson et al. 2000.

One of the most fundamental assumptions of this thesis is that infrasystems contribute to considerable environmental impacts, and that the path to a sustainable development therefore presupposes changes of infrasystems. Environmental problems, and change conditions associated with infrasystems in general, which are starting-points of papers 1 – 3, were surveyed in reports Jonsson 2002 (literature review: relations between infrastructure and urban structure); Jonsson 1998 (surveying infrasystem related innovations); and in Jonsson et al. 2000.

Among the infrasystems, the most frequently treated area of application in my research work has been transports. Environmental effects of transports, and how to mitigate those effects (concerning all papers, but paper 3 – 5 in particular), are underlying themes in Jonsson et al. 2006 (energy and transport assessments in Swedish official Government reports); Åkerman et al. 2000 and 2006 (future studies of the transport systems of Sweden and Stockholm, respectively); Dreborg and Jonsson 2006 (feed-back processes in the transport system); Jonsson and Johansson 2003b (indirect effects of infrastructure investments); Jonsson 2005 (systematisation and quantification of transport energy); Jonsson 2004b (review of environmental assessments of regional infrastructure plans); and Jonsson 2002 (literature review supporting Jonsson and Johansson 2003b).

Only paper 4, aiming to contribute to the development of Strategic Environmental Assessment (SEA), has a clear methodological aim. Paper 4 is partly inspired by Johansson et al. 2004 (SEA development for the Swedish Ministry of Defence); Jonsson 2004b; and Jonsson 2002; but based on Jonsson and Johansson 2003b in particular. Publications supporting this thesis with empirical elements are primarily Jonsson et al. 2006; and Jonsson 2005, 2004b and 1998.

While paper 1-3 mainly have a conceptual character, and paper 4 has a methodological ambition, paper 5 rather has the character of plain quantitative result accounting, regarding energy use in the transport sector. Paper 5 summarises parts of Jonsson 2005, which was a pilot study providing inputs to Åkerman et al. 2006.

In essence, a number of research projects, and some projects mainly with an investigative character, have in various degrees contributed to the papers attached to this thesis. Having the previous discussion in mind, this of course means that the unity of the thesis in general, and the cover essay in particular, was not taken into consideration when the papers originally were written. Consequently, some theoretical passages are repeated, and my view upon some states of things might have altered during this period, which should be traceable. Nevertheless, writing this cover essay has been a great opportunity for me, to summarise, and hopefully even to renew, some of the theoretical elements that have surrounded my everyday work since 1998. But before entering the theory chapter, a brief discussion over what fields of research, or academic disciplines, this thesis could be associated with might be fruitful.

1.4 An interdisciplinary field of research

This is a dissertation in the research subject Infrastructure and Planning, with specialisation in Environmental Strategies Analysis. The responsible department at the Royal Institute of Technology is Urban Planning and Environment, at the School of Architecture and the Built Environment. The purpose of combining already wide fields such as architecture, urban studies, infrastructure planning, and environmental strategies, is to create “a systemic view of the built environment, housing and natural resources” (KTH 2006), and the research ”is aimed at creating the best possible preconditions for sustainable society” (ibid.).

The notion of sustainable development constitutes the context of this thesis (section 2.1). It goes without saying that sustainability issues not only are complex and interrelated, but also demand co-ordinated efforts from a great range of sectors of society and many academic disciplines. The theoretical approaches setting the tone in this thesis are to some extent various systems perspectives in general (section 2.2), but the LTS perspective (section 2.3) and the SITOP concept (section 2.4) in particular.

The LTS perspective emanates from the field of History of Science and Technology, which is an interdisciplinary field of research dealing with the driving forces behind technical and industrial change, and the social and cultural effects of technology, in a historical perspective (ibid.).

The SITOP approach, which is a change perspective that is being developed within an ongoing research programme at the Royal Institute of Technology, has theoretical elements emanating from e.g. built environment analysis, environmental strategies analysis, scenario methodology and future studies, and political science (Svane 2005a and 2006).

In contemporary academic dissertations dealing with inter-, multi-, or trans-disciplinary problems, the research paradigms presented by Gibbons et al. (1994) are often discussed. Gibbons et al. argue that the production of knowledge is advancing into a new phase. They highlight the trend that research of today shifts from university controlled, discipline-based Mode 1 research, to multidisciplinary, problem based Mode 2 research.

Mode 1 research aims at producing new theories, while Mode 2 research often focuses on practical utility. The procedures of Mode 2 research are also often considered more flexible and interactive than in Mode 1. Moreover the researchers and research object are clearly separated in Mode 1, while participative research could be a feature of Mode 2 (Elfors 2006, drawing on Nowotny et al. 2001).

Gibbons et al. (1994) state that “the socially distributed nature of Mode 2 knowledge production is above all embodied in the people and the ways they are interacting in socially organised forms” (p. 17), leading to the conclusion that tacit knowledge is important and needs to be managed and utilised in new ways, e.g. in quality controlling contexts.

The scope of this thesis is definitely interdisciplinary, highlighted by the socio-technical perspective, and the LTS and the SITOP approaches. Especially the SITOP approach is characterised by many Mode 2 features, e.g. is problem based, aims at practical utility, and involves many actors. In spite of that, this cover essay should not be seen as a distinct example of Mode 2 research. I would rather say that this thesis is an attempt to combine some Mode 2 research fields in a Mode 1 context (university controlled, based on academic disciplines, and aiming at theory development), however, with a Mode 2 focus (problem based). And the problem of interest in this cover essay – sustainable development – will be elaborated in the first part of the following chapter.

2. Perspectives on relevant research areas

In this chapter the theoretical body of the thesis is presented. Sections 2.1 and 2.2 have an introductory character, reflecting upon the notion of sustainable development, and surveying some systems perspectives, respectively. After that, the two principal theory parts of this cover essay are presented. Section 2.3 elaborates on infrasystems as socio-technical systems, primarily by way of using the Large Technical Systems (LTS) perspective. In section 2.4 the principal change perspective used in this cover essay is presented: the Situations of Opportunity (SITOP) approach. Since the SITOP approach still can be considered as a draft theory, the relations to some established concepts, e.g. formative moments, policy windows, formal rationality, and path dependency, are also discussed in section 2.4.

2.1 Reflections on sustainable development

Man and man-made systems are dependent upon nature. Nature delivers a number of ecological services, e.g. photosynthesis, production of soil, pollination of crops, biological diversity, maintaining the composition of the atmosphere, levelling out the climate and maintaining other conditions for life of animals and plants in seas and on land. In all probability, these services cannot ever be substituted by human constructed equivalences in a large-scale manner (see e.g. Daily 1997, for an elaborated discussion on ecological services). Among other things, the insight of the character of these services lead to the apprehension that the economical system is a subsystem of nature and that nature sets physical limits to the scale of how much energy and materials that can be converted or processed in the economical system. At the same time, the use of resources is unequally distributed in a global perspective.

The notion of *sustainable development* has come to symbolise the striving for increasing quality of life of humans without eroding the resource base. The expression got widely spread after the work of the so-called ‘Brundtland commission', which defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

The definition is vague and interpretations are numerous. However, the following themes are usually included in the interpretations (Morita et al. 1993):

- Preserving a viable environment.
- Increased, or preserved, quality of life.
- Fair distribution between present and future generations.
- Fair distribution within generations.

In general, sustainable development is divided into the three interrelated environmental, social, and economical dimensions. The relations and order of precedence between the dimensions are well-debated questions. Based on arguments similar to the ones stated in the introduction in this section, one view might be that changes in the environment lead to social and economical consequences – i.e. a social and economical sustainable development presupposes an environmental sustainable development. Obviously, an ecological sustainable development does not guarantee sustainable social and economical developments. On the contrary, issues such as reducing poverty or the conflict between decreased energy use and economic growth just mirror the magnitude of the challenge that the world is facing – to manage a global social and economic development, which neither deteriorates the ecological systems nor exhausts the natural resources. When trying to translate the vague interrelated, perhaps conflicting, goals into quantitative measures, it becomes clear that non-trivial changes are needed. This can be illustrated through the following example based on Peter Steen et al. (1997), where future sustainable transports in Sweden are considered:

If considering a global mean temperature increase of 1,1–3,3°C to be acceptable, i.e. in line with sustainable development, the future atmospheric concentration of CO_2 must be stabilised around 450 ppm (parts per million) – in comparison with 368 ppm in year 2000, and 280 ppm before industrialisation started in the 18^{th} Century. In the long run this stabilisation requires a reduction of roughly 50% of CO_2 emissions seen from a global perspective. However, considering that CO_2 emissions should be equally distributed per capita around Earth, a reduction of circa 80% is required in Sweden (Steen et al. 1997, based on IPCC data and Swedish emission statistics).

Climate change is one of the most significant challenges regarding environmental sustainable development, affecting man-made constructions and systems (e.g. infrastructure and buildings), and other human livelihoods and concerns (e.g. health, safety and food production), as well as potentially immense consequences on biodiversity and the long-term production capacity of the biological systems. Closely related to the issue of climate change is the use of energy. However, the use of energy as an important sustainability aspect is not only a question of emissions – causing climate change, acidification, eutrophication and local pollution – but also closely related to the rate of flow of materials and other resources in society. Since no material cycle is entirely closed, unnaturally high concentrations of various substances will occur, which can affect human health and ecosystems, the spread of toxic substances disregarded.

In this thesis the specific environmental effects of the use and operation of various infrasystems are not further elaborated. However, it is safe to say that infrastructure and infrasystems not only were prerequisites for the incomparable economic development and welfare increase during the last centuries – they have also facilitated the intensified use of natural resources and caused negative effects on ecosystems.

The relations between infrasystems, development of society, and environmental impacts are complex and thus not very easy to grasp. The complexity is also obvious when it comes to understanding the dynamics and conditions of change of large socio-technical systems such as infrasystems. Understanding the interplay between such disparate topics as technology, human behaviour, policy, and social and environmental aspects as a system of dynamic relations might be fruitful, which is yet another reason to discuss systemic views, or systems perspectives. This is the topic of the following section.

2.2 Summarising some systems perspectives

The purpose of this introduction, covering some system definitions, theories, perspectives and approaches, is not claimed to be a complete survey over the wide field of systemic thinking, but rather to indicate the position of the socio-technical systems perspective and the infrasystem concept (elaborated in section 2.3) in relation to other system approaches and traditions. One obvious dividing line between the socio-technical systems perspective and most of the systems perspectives presented in this section is the underlying academic tradition. LTS, and the socio-technical systems perspective, emanate from the discipline of history of technology. Many other disciplines use systems perspectives in various contexts. Some of them are briefly touched upon below, e.g. mathematics, modelling and numerical analysis, in such applications as economy and biology, or traditional systems analysis and operations analysis, for example making decision analysis, in military contexts. Moreover, there are great differences in the meanings associated with the word 'system' – from concrete and simple, to the opposite.

So, what is a system? Systems are regularly defined by *system boundaries*, demarcating a certain system from its *surroundings*. The system consists of *components* and *relations* between the components, forming some sort of *entirety*. In *System – att tänka över samhälle och teknik* (translation: *Systems – reflecting on society and technology*), Lars Ingelstam (2002) presents a broad survey over how to define and understand systems, by way of navigating through the 'system history' involving various perspectives and theorists, however primarily in the mid and late 20th Century. Ingelstam (2002) is the key reference to this section of the cover essay.

One example of an early systems theorist surveyed by Ingelstam (2002) is the 'father of cybernetics', the mathematician Norbert Wiener, using the word 'machine' rather than system, and highlighting relations rather than components. Another prominent figure when it comes to theorising on systems on this 'meta-level' is the biologist Ludwig von Bertalanffy, associated with the General System Theory (1968), promoting the broad applicability of system research and systems analysis.

To structure the field of system research traditions, Ingelstam uses a classification model inspired by Luhmann (1995). Certain system approaches or traditions can either be associated with one or several of the following main variables or system families (Ingelstam 2002, p. 28):

- Machines
- Organisms

- Social systems
- Socio-technical
- NTS (Nature–Technology–Society, to emphasise that beyond socio-technical variables, nature and natural resources also are main variables of the model).

The perspectives of greatest interest for the research theme in this thesis are machines (i.e. technical components and their relations), socio-technical aspects and NTS.

When trying define a large and complex system including a great number of 'cause-effect'-relations it is easy to fall into the trap leading to the trivial conclusion that 'everything is related', which is a dilemma also elaborated by Ingelstam (2002, pp. 23-24). Nature and society together form a giant system composed by a great number of subsystems. When setting system boundaries in a research context, the purposes of the study, biases, values and professional background of the researcher always influence on the resulting system entirety. For example, what is an electricity system? It could be where ever we can find traces of activities dependent on electricity. It could also be delimited to the system managed by a certain actor, e.g. an energy producer. If that company also provides other services, e.g. district heating, fuels and Internet access, are those also parts of the electricity system? Is the finance market, which usually is a prerequisite for building capital-intensive infrastructure, and the insurance market also parts of the electricity system? There are of course no definite answers of how to set the *system boundaries* around the *related components*. When Hughes (1987) defines 'technological systems', the system boundaries are set by the criterion that related components is not enough, the components have to be *interrelated* to be included in the system, i.e. one-way influence is not a system criterion, there has to be interaction.

Generally however, systems are stipulated on the basis of the specific perspective, or question, of interest and of what is manageable. Ingelstam (2002) states that the intellectual method of distinguishing systems (and subsystems) from their surroundings should be based on rationality. In other words, what is the purpose of defining a system? What is the problem? Whose is the problem? The answers to these questions should guide the process of delimiting a system.

A similar view is presented in *Systems Thinking, Systems Practice* by the acknowledged systems thinker Peter Checkland (1999). Checkland calls attention to the learning aspects of systems analysis, arguing that there are many system models which *can* be built; “so the first choice to be made is of which ones are likely to be most relevant (or insightful) in exploring the situation” (ibid., p. A7). As Ingelstam (2002), Checkland also presents a systems typology, with the following systems classes (Checkland 1999, p. 112, elaborated from Checkland 1971):

- natural systems,
- designed physical systems,
- designed abstract systems, and
- human activity systems.

Natural systems include man, who can create human activity systems and designed physical, or abstract, systems. Checkland’s typology does not give unambiguous answers on how to classify infrasystems. From a technical perspective, infrasystems are designed physical systems. However, infrasystems as socio-technical systems include human activity systems interplaying with technology. On a meta-level, the models of thought used to understand the relations between actors and components in a socio-technical system can be interpreted as a designed abstract system. Moreover, infrasystems often include and are often dependent upon natural systems.

In the context of making system classifications, tools to stipulate systems characteristics might be useful. One approach on how to illustrate *systemicy* is presented by Svante Beckman (1994) (inspired by evolutionist Herbert Spencer, 1851/1970):

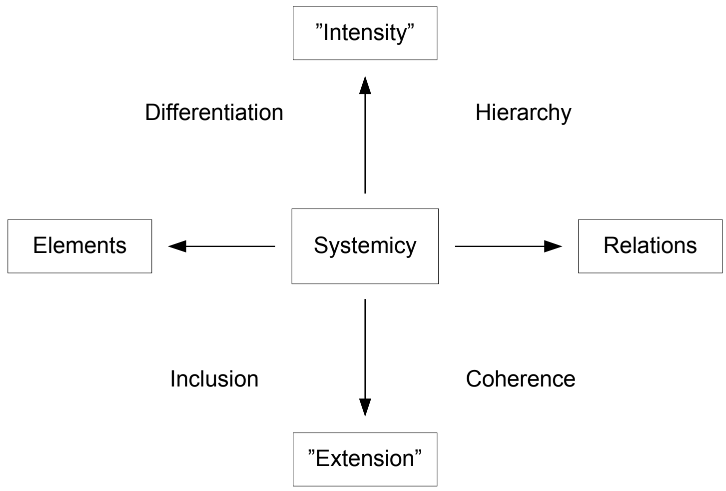

Figure 2. The basic dimensions of systemicy. Beckman explains the figure: "The figure names four interdependent master dimensions of systemicy which are at least in principle measurable. They are identified with the help of a simple two-dimensional conceptual map and are distinguished between what can be roughly referred to as "intensity" and "extension" on the one hand, and between a reference made system elements and to system relations, on the other. The overall systemicy of a unit is a function of its values in these four dimensions: how many elements are included in the system (inclusion), how many different kinds of elements it contains (differentiation), how cohesive the relations between elements are (coherence) and, finally, how many levels of hierarchy there are." (Beckman 1994, p. 314).

The systemicy dimensions are applicable not only to phenomena with a systemic character such as a business organisation or a body of scientific knowledge. Beckman argues that the nature of interdependency between the four dimensions of systemicy is that "change in any one of them requires and permits changes in the others" (ibid., p. 315). This view highlights the complexity and relations *within* systems.

A diametrically opposed perspective is to consider systems as 'black boxes', connected with the outer world only through well-defined inputs and outputs. The 'black box'-metaphor is generally not in line with the tradition of how to approach socio-technical systems, which rather can be characterised by its focus on the components, actors and relations that can be found within the 'black box'. Yet in many branches of *systems analysis* – which is the final theme in this brief survey –

the ‘black box’-metaphor can be useful, bringing clarity within simplified pictures of complex systems with a large number of components, relations and subsystems.

Systems analysis (SA) has its roots in operations analysis (OA) in Great Britain during World War II and was primarily developed in military research contexts in the post-war era (Quade and Boucher 1968; Ingelstam 2002), primarily at the RAND Corporation in the U.S. (e.g. Kahn and Mann 1956), but also in Sweden at the National Defence Research Establishment (FOA) (surveyed by Kaijser and Tiberg 2000; Ingelstam 2002). However, later on, systems analysis also found civil applications.[2]

The essence of systems analysis is that complex groups of problems with coherent and interconnected aspects and variables can not immediately be solved in a straightforward engineering manner. Instead, the problem solving process must include, and be preceded by, an analysis of the systemic characteristics of the question at issue (see e.g. Churchman 1968; Ingelstam 2002). Often mentioned standard works in systems analysis field are *The Systems Approach*, by C. W. Churchman (1968), and the three volumes of *Handbook of Systems Analysis* (Miser and Quade 1985 and 1988; Miser 1995).

Traditional systems analysis generally makes a clear distinction between technology, the actors controlling the system, and other people dependent upon – or acting within – the system. This is a different approach compared with the socio-technical systems perspective, promoting the metaphor of a ‘seamless web’ (discussed in section 2.3), where technical, economic, social and political aspects are intimately intertwined.

To sum up, the various systems perspectives differ a lot. Checkland (1999) argues that the general dividing line concerns how the different traditions handle the relation between the system (which is a delimited part of reality) and the model (which is one of many conceivable representations, or images, of reality). The relationship is

[2] A number of Swedish policy-oriented future studies originate from the tradition of systems analysis. Ingelstam (2002) points out that the first generation of Swedish future researchers surprisingly often had with a past history from the National Defence Research Establishment (FOA), e.g. Peter Steen, Arne Kaijser, Måns Lönnroth and also Lars Ingelstam himself. Today, the future studies branch (with civil application) is an integrated line of research at the Swedish Defence Research Agency (FOI) (which is the present name of old FOA), represented by e.g. Karl Henrik Dreborg, E. Anders Eriksson, Jessica Johansson, Annika Karlsson-Kanyama, and Henrik Carlsen.

decided by the purpose of using a systemic view, or by the specific problem to be solved. And of course, in many cases the meaning of the word 'system' equals the 'model', i.e. the described system is considered a model of reality rather than a part of reality. Anyhow, some of the perspectives described above primarily deal with the philosophical aspects of reality, not paying that much attention to models. Other perspectives, aiming to solve problems in a quantitative manner, need to conceptualise systems into models.

When considering infrasystems, we can, first of all, establish the fact that the technical and physical components (e.g. wires, pipes, mobile phones, roads and power plants) considered as parts of infrasystems are real – i.e. the systems are parts of reality – constituting a physical point of departure for various models such as the 'seamless web', which also includes 'invisible' components.

2.3 Infrasystems as Large (socio-)Technical Systems

As mentioned in the introduction, the notion of *infrasystem* was derived and developed by the Swedish historian of technology Arne Kaijser: "The concept 'infrasystem' is used to denote a certain category of large technical systems, and the study of infrasystems partly falls within a research field that is called the Large Technical Systems approach (sometimes abbreviated LTS)" (Kaijser 2003, p. 154). According to Kaijser's definition (1994), infrasystems are large technical systems with a public character – they are equally accessible for all potential users within the geographical area covered by the system. Infrasystems also imply considerable and long-term conditions for private and public activities, e.g. trade, industrial mobility, education and national defence. Originally Kaijser (1994) divided infrasystems into the categories transportation (of people and goods), energy supply, and communication (of information). In later works of Kaijser (e.g. in chapter 1, in Jonsson et al. 2000), urban infrastructure systems such as water and sewage, and waste management, are also embraced by the infrasystem definition.

Kaijser (1994) analyses the characteristics of infrasystems by way of addressing four different perspectives:

- technology,

- geography,
- economy, and
- institutions.

Various characteristics of infrasystems coined by Kaijser, e.g. classifications of networks and flow types, are summarised and further elaborated in paper 1 of this thesis (primarily technical and geographical characteristics).

As mentioned in the end of the previous section, from a socio-technical perspective infrasystems can be understood as a *seamless web* of interweaved technical and social aspects and components (Hughes 1986). That is to say that infrasystems should not be treated only as sets of coherent technical components separated from actors and circumstances affecting the systems. The definition of infrasystems also includes the people and organisations that plan, build, run, and use the systems, and the economic and legal conditions for the activities (Kaijser et al. 1991; Kaijser 1994). Smooth operation and successful development of an infrasystem require that the physical, organisational, legal and economic elements are matched to each other, which can be exemplified by quoting Kaijser et al. 1991 (p. 20, drawing on Lilley 1973):

> "1825 saw the construction of the world's first public railway in northern England, between Stockton and Darlington. Private railways had been built earlier than this, mainly to serve mines. The company that built the railway modelled it on the structure of the existing canal system, and organised its activities in the same way as canal traffic. This meant that anyone, having made suitable payment to the company, could traffic the railway with his own rolling stock, which could be pulled by horses or locomotives. The railway was built as a single track, with parallel tracks for passing built at 400-metre intervals. Traffic increased at first in accordance with the company's plans, but as it increased, the growing number of meetings on the single track resulted in longer journey times. The organisation and the technology were not suited to each other.
>
> When the world's second public railway was built in 1830 between Liverpool and Manchester, the developers had learnt from experience. They did not stop at building only the railway, but purchased carriages and locomotives and ran the railway under their own management. This time, increasing traffic meant that operation improved, as it resulted in more frequent trains and shorter journey times.
>
> It is interesting to note that the physical systems were much the same in both companies, but that the differences lay in the organisational aspect, with resulting

fundamental differences in overall operation. This could well be regarded as something of a socio-technical revolution."

The dynamics of Large Technical Systems à la Hughes and Kaijser

The study of historical socio-technical processes of change constitutes the foundation of the LTS approach. A prominent figure in this line of research is the American historian of technology Thomas P. Hughes, the author of *Networks of Power – Electrification in Western Society, 1880-1930* (1983). The LTS approach can be used when large, complex and technology intensive systems are studied and consideration of the interaction with other systems and the surrounding society is required. The systems are complex in the sense that they are built up from a large number of components – technical and organisational – of various characters. The temporal aspect and the analysis of the long-term development of socio-technical processes is a cornerstone of the LTS tradition, whose bearers often are historians of technology. Moreover, the LTS approach is regularly associated with a broader field of research called Science and Technology Studies (STS), including e.g. studies on the sociological aspects on technological change.

Kaijser (1994) defines infrasystems as socio-technical systems. Hughes however, prefers the designation 'technological system', rather than 'socio-technical system'. Nonetheless, he states that "[t]hey are both socially constructed and society shaping" (Hughes 1987, p. 51). Moreover Hughes uses a more distinct definition than Kaijser, considering what should be included in the system (ibid., p. 53) (also briefly mentioned in section 2.2):

> "Two kinds of environment relate to open technological systems: ones on which they are dependent and ones dependent on them. In neither case is there interaction between the system and the environment; there is simply a one-way influence. Because they are not under system control, environmental factors affecting the system should not be mistaken for components of the system. Because they do not interact with the system, environmental factors dependent on the system should not be seen as a part of it either."

Hughes and the LTS tradition have been criticised, e.g. for exaggeratedly highlighting the significance of the so-called *momentum* or *system builders* (described below) (see also elaborated critique discussion further on). However, Hughes' originality is acknowledged, and lies primarily in the introduction of interesting notions and metaphors and also in his perspective of how society has affected technology, rather than the other way around (which is a research field many writers have paid attention to, according to Hughes).

In Hughes' (1983) analysis of the electrification in Western society, a key feature is that every large technical system goes through different phases, e.g. invention and development, and growth. Every phase is characterised by different kinds of problems. Kaijser (1994) develops Hughes' model and describes the dynamics of infrasystems through three different phases of development;

- establishment,
- expansion, and
- stagnation,

respectively described below (mainly based on Kaijser 1994 and 2004; and on Hughes 1983 and 1987, also summarised in paper 2 in this thesis).

Establishment

The establishing phase is characterised by technical and institutional uncertainty. The process often involves more than one actor or party of interest. Often the State and local authorities are involved. Hughes uses the concept of *technological style* to describe how the establishment of an infrasystem is influenced by each country's specific political, social, economical, cultural and geographical characteristics. Systems requiring heavy investments and great coordination, such as national railways, generally benefit from centralised political power structures and a developed finance market. Moreover, the system design is naturally dependent upon geography in terms of mountains, lakes and so on.

Successfully established system arrangements are often copied by other countries, regions or cities. Hughes (1983) calls this phase *technology transfer*. However, Kaijser rather highlights institutional innovations as common feature of many systems in early stages of their development. Consequently, Kaijser prefers the designation *institutional transfer*: "The institutional frameworks shaped for the first infrasystem in a city or a country have often served as a model when infrasystems have been established later on. This 'institutional transfer' has led to the emergence of specific national institutional regimes for infrasystems" (Kaijser 2004, p. 159). The management model of the railway between Liverpool and Manchester in 1830, referred to on the previous section, is one example.

Expansion

The expansion phase is characterised by common confidence in the system and its future growth. The expansion phase leads to increased quality through geographical expansion (i.e. reaching more users and locations) or expansion into new fields of utilisation (e.g. when electricity, originally developed for lighting in cities, found numerous of other applications). A *system culture* develops among the parties concerned, i.e. a common view upon what is rational and desirable in the future development of the system. The process of development is characterised with increasing *momentum*, but also with *inertia* – it is hard to decide on something that is not in line with the current system culture. Hughes introduces the concept of technological momentum – on the analogy of the mechanics' impulse law, in the field of physics – by way of describing the expansion phase of the poly-phase electric system (1983, p. 140):

> "A supportive context, or culture, formed rapidly. Men and institutions developed characteristics that suited them to the characteristics of technology. And the systematic interaction of men, ideas, and institutions, both technical and nontechnical, led to the development of a supersystem – a sociotechnical one – with mass movement and direction. An apt metaphor for this movement is "momentum". So reinforced by a cultural context, and interacting in a systematic way with the elements of that context, the universal system, like high-momentum matter, tended in time to resist changes in the direction of development. Development proceeded along lines that could be extrapolated. The universal system gathered a conservative momentum. Its growth generally was steady, and change became a diversification of function."

With reference to *inertia*, the state of an infrasystem organisation with a strong system culture, propelled by a strong momentum, can be labelled *dynamic conservatism*, a concept introduced by Donald Schon (1967), however also elaborated in an infrasystem context by Kaijser et al. (1991): existing technical and institutional solutions are constantly improved, however new technology and new organisational forms are considered as threats against the predominant order. Dynamic conservatism grows stronger during the expansion phase, and can generally be considered as fully developed in the stagnation phase.

Also associated with the expansion phase are bottlenecks, i.e. problems of technological and/or institutional nature – in Hughes' (1983) terminology: *reverse salients* and *critical problems*. A reverse salient can be interpreted as an unbalanced development, or with other words, an institutional or technological component lagging behind the system's overall progress. *Reverse salient* is an expression borrowed from military terminology: a front moving forward but with a partial lag, or an inward bend. A reverse salient can for example be when a telephone system has expanded in terms of number of users and traffic volume, while some components of the network have not been extended or updated, i.e. there is a risk of overloading. Using Hughes terminology, problems labelled reverse salients can be solved through *conservative inventions* (compared with *radical inventions*, with the potential power to evolve into new systems) (Hughes 1987).

Critical problems is however a wider conception: when a reverse salient has been identified and demarcated – i.e. the problem has been defined and formulated – it is considered a *critical problem* among the promoters of the system, which must be solved in order to develop the system further. Referring to the previous example regarding telephone systems, the *critical problem* could be formulated as how to solve the capacity problem in general, including developing new components, also addressing integration and compatibility issues, but it can also include broader solutions, such as steering the traffic – i.e. levelling the *load curve* – by way of implementing differentiated pricing (e.g. reduced fees at night).

The significance of *load factors* and *load curves* for the expansion phase is highlighted by Hughes (1987). The load factor is the ratio of average output to the maximum output during a certain period, e.g. the Swedish electricity system generally produces approximately 60% of its capacity during summer time (Swedenergy 2006, p. 25). Expansion can involve increased volumes or network extension, but also increased diversity in terms of users and points of time of consumption. Due to the high capital intensity of infrasystems, a high load factor is desirable for an infrasystem organisation: "[...] the load curve that indicates the load factor, or the utilisation of investment and the related unit cost, is a much relied on indicator of return on investment" (Hughes 1987, p. 72). However, a smooth load curve is also desirable, in contrast to sudden peaks of demand or down periods. To be able to handle the peaks, the infrasystem organisation may feel forced to build up expensive over-capacity, e.g. additional power plants – leading to increased capital costs – while down periods lead to poor return of investments since the full production capacity is not utilised. A favourable load factor due to increased diversity might however contribute to further expansion: different users are using the system for different purposes at different times, generating a smooth load curve. Hughes states that "[t]he load factor is, probably, the major explanation for the growth of capital-intensive technological systems in capitalistic, interest-calculating societies" (ibid.).

Stagnation

The last phase of the development of infrasystems – stagnation – is characterised by a decreasing momentum. System growth diminishes because the market, or the economies of scale, has reached saturation level (e.g. electricity to households) or because of the competition from other systems (e.g. rail freight). When development stagnates, the system consolidates on a stable level (steady state) or follows a downward trend. Kaijser (1994) uses the designation 'stagnation', while Hughes (1987) uses 'consolidation'. My interpretation is that 'stagnation' means a decrease in momentum, which may result in 'consolidation', or 'steady-state', but can also bring about a downward trend – 'decline' – ultimately resulting in shutting the system down.

The notion of *radical problems,* or *radical changes*, is relevant when it comes to competition from new systems, actors or services, e.g. when canal traffic was driven out of competition by railways. When radical problems, or changes, threaten the existing order, the leading actors tend to meet the changed conditions with defensive actions rather than in an adaptive manner (compare with *dynamic conservatism* in the expansion phase). This is another drawback of a strong system culture with high momentum: the socio-technical determinism cultivated within the system makes the system vulnerable to radical changes.

Radical problems, or changes, can either have an internal or external origin. Competition from new independent systems is of course an external factor, but can also be the long-term result of an internal problem solving process: "When a reverse salient cannot be corrected within the context of an existing system, the problem becomes a radical one, the solution of which may bring a new and competing system" (Hughes 1987, p. 75).

Kaijser points out another cause to infrasystem stagnation, namely when *economies of reach* transform into *diseconomies of reach* (2004, p. 159):

> "In the case of road traffic in urban regions, additional cars have steadily increased the congestion on existing roads, and due to a scarcity of land it has been difficult to build additional roads. The more cars, the longer it takes for each to reach its destiny, and this of course hampers the further expansion of car traffic."

Kaijser (2004) also argues that due to the frequent delays of flights in Europe, a similar process affects aviation systems. This might benefit personal transport with high-speed trains between major urban centres in Europe.

System builders – the main actor perspective of LTS

The development phases, and the various characters of the problems associated with each phase, are central in Hughes' approach. Another key concept of LTS is *system builders*, whose importance in the development of a socio-technical system is emphasised. According to Hughes, the driving force of system builders originates from the vision of how to integrate the system components into a functioning entirety, and the desire to control this development. A system builder can be an individual, an informal group of people, a project group, or an organisation. However, Hughes has primarily focused on individual pioneers such as Thomas A. Edison and Alexander Graham Bell in his studies, rather than on groups or organisations (see e.g. Hughes 1989: *American Genesis. A History of the American Genius for Invention*). System builders (when referring to individuals) generally are engineers, managers, innovators, politicians or financiers by profession. However, Hughes maintains that they also should be considered as entrepreneurs.

Due to Hughes' great focus on system builders, and as mentioned earlier, highlighting the significance of momentum, the LTS approach has been questioned. Some of that critique is summarised in the following section.

Summarising some critique of the LTS approach

The LTS tradition is not a completely homogeneous scientific line of research. However, a fairly common view upon the main features of LTS evolved via a number of conferences and anthologies during the late nineteen eighties and nineties. Sociologist Jane Summerton (1998) highlights some common features of the LTS-oriented case studies: the usage of metaphors related to heroes and heroic efforts, evolutionary processes, and the occurrences of crises and periods of stability in the systems' development processes. However, Summerton also notes that the dominant perspective – the actor perspective or the systems perspective – alternates. On the one hand the importance of *system builders*, guiding the system development, is emphasised, on the other hand the notion of *momentum*, i.e. an inherent force within the system itself, is considered important for system growth and development.

The critique discussion summarised in this section will be one of the points of departure of the synthesis presented in chapter 3.

Partly based on the discussion above, Summerton (1998, pp. 33-35) summarises some critique against the LTS approach divided into three main themes:

- The features of technological determinism, primarily in Hughes' research. Especially the importance of *momentum* is questioned with the essence that technological development is never predetermined (Bijker and Law 1992; McGuire et al. 1993).
- A far too one-sided focus on heroic actors, i.e. the successful *system builders*, and their will to control and expand the systems. This promotes a biased top-down perspective. Moreover the researcher's focus on following a certain actor's efforts might obscure the importance of other actors and aspects relevant to the development of the system (Law 1991).
- The lack of a gender perspective on how and why the systems evolved.

Another interesting elaboration of critique is presented by Lena Ewertsson (2001), which here is condensed into two main points, concerning two concepts of Hughes:

- The concept of *technological style*, which generally refers to the ‘style’ of a certain nation, is less applicable today when mature systems undergo change due to globalisation or European integration. Moreover, the new information-based systems have no immediate relation to the physical territory of particular nation-states (e.g. the Internet).
- The idea of *reverse salients*, i.e. problems constraining continuing expansion or progress of a system, is problematic due to the one-sided focus on certain system builders. “*To whom* is it presumed to be a reverse salient? *What system* is perceived as being constrained in its expansion or progress by any particular reverse salient” (Ewertsson 2001, p. 369).

Another aspect limiting the applicability of the LTS approach, when it comes to understanding infrasystems in change, is the fact that Hughes’ theory building to a great extent is coloured by the results of studies of successful, technology driven implementations (and expansions) of investment intensive, grid-based systems. Due to the legacy of Hughes –strong focus on easily identifiable system builders and system cultures – heavy and controllable, often also centralised, infrasystems such as electricity and railways have been carefully explored at the expense of loosely coupled systems such as road transports. Moreover, great technological innovations and first-time establishments of systems are generally the centres of attraction, rather than mature infrasystems. Of course, beside the mainstream there are exceptions. For example, Pär Blomkvist has applied the LTS perspective on the rise of automobile society (e.g. Blomkvist 1998 and 2001), constituting an example of the former. Another example is presented by Tomas Ekman who has investigated the decline of tram traffic in Stockholm by way of adding a socio-technical perspective on the struggle for road space between cars and public transport (e.g. in Ekman 2003).

Anyhow, critique of this kind should probably not be addressed to the works of Thomas P. Hughes, who never has claimed to be the originator of an all-embracing theory on how to understand infrasystem change in general. However, LTS supporters (such as myself) sometimes tend to exaggerate the universal applicability of Hughes’ approach in their efforts of highlighting the socio-technical aspects of change.

The missing systems user perspective

The critique discussion will be ended with a theme previously briefly touched upon – the problem associated with the predilection for *system builders* in the LTS approach. This might imply a somewhat narrowed top-down perspective resulting in a far too one-sided focus on important individuals, or 'heroes', and their technology, rather than the end-consumer, the services provided by the system or the applications of these services.

The lack of the systems user perspective is however not a unique feature of the LTS approach. Aspects associated with the end-users are often also neglected in other research traditions analysing systems. One speculative explanation could be that this is a result of the mid-20th century successes for the 'predict and provide' paradigm, in the mixed economies of that time – at the expense of the market oriented 'supply and demand', where the interplay between end-users (or consumers) and infrasystem service providers (or producers) is a key feature.

Ingelstam (2002, p. 248) questions the common LTS mode of procedure to define a system set out from its technical core, instead of starting out from the function of the system. An attempt to highlight the functions and services of infrasystems, rather than technology – including their applications of the services in the form of utilities and conveniences, and their underlying needs – is presented in paper 2 in this thesis (see elaborated discussion in section 4.2).

Social Construction of Technological Systems

A school of thought closely related to LTS is technically oriented social constructivism, abbreviated SCOT (Social Construction of Technology) presented in the frequently cited *Social Construction of Technological Systems*, edited by Wiebe Bijker, Thomas Hughes and Trevor Pinch (1987), which to some extent can be seen as a result of critique of Hughes' approach – however also through mutual inspiration. The systems approach by Hughes, presented as 'The Evolution of Large Technical Systems' (based on Hughes 1983), is one of three key parts in the theoretical body of this anthology. The other two, briefly surveyed below, are:

- The social constructivist approach (regarding technology[3]), introduced by Pinch and Bijker. This approach is usually referred to as the actual SCOT approach.
- The actor-network approach, or Actor Network Theory (ANT), presented by Michael Callon, but also associated with Bruno Latour and John Law (see e.g. Latour 1987).

The social constructivist approach emphasises how new *technological artefacts* develop depending on how *relevant social groups* interpret and utilise the artefacts, i.e. exploring the possible range of application. The early development of the bicycle in the 19th Century is used as an example (see also Bijker 1995) of how different social groups influence the design of a technological artefact by way of addressing unique problems for each social group respectively. This process is stabilised when most of the groups can agree upon that the problems have been solved – *closure* has been reached. In other words, the fundamental features when it comes to the design of the artefact do no longer change. The solving of all the initial problems is however not a necessary prerequisite to reach closure. "The key point is whether the relevant social groups see the problem as being solved" (Pinch and Bijker 1987, p. 44), e.g. when the evolved early bicycle design finally was considered to handle problems associated with for example safety, speed, vibrations, and women's clothing.

The actor-network approach (in the context of SCOT) essentially addresses the importance of symmetrical treatment of technology, actors and other influential circumstances in order to explain, or foresee, the development of a system or other phenomena with technical features. The distinction between 'hard' and 'soft' aspects and units is broken down in ANT. Human actors, as well as technology and nature are treated as, somewhat equal, elements in variable actor-networks – in contrast to predefined systems, which regularly need to redefined or that, according to Callon, the system relations continually must be labelled in terms of 'outside' or 'inside' of the system, during analysis. Callon concludes that "[b]y abandoning the concept of system for that of actor network, I believe we are taking Hughes' analysis – neatly

[3] In comparison with *The Social Construction of Reality*, by Berger and Luckmann (1966), among other things explaining the organisation of society as a human product of socio-cultural and psychological formations ('homo socius') rather than a result of man's biological constitution ('homo sapiens').

summed up in the ambivalent title of his book, *Networks of Power* – a step further" (1987, p. 101).

The three approaches, social constructivism, actor-network approach, and LTS, are together presented as a potential research programme "to deal with this seamless web of technology and society" (Bijker et al. 1987, p. 10). The approaches differ but are at the same time interrelated. The interpretation of Ingelstam (2002) is that while LTS tends to focus on technology and social constructivism highlights social aspects, ANT persists the importance of symmetry between technology and social aspects. Anyhow, despite of the fact that the three approaches are not integrated into one single approach in this anthology, the social constructivist approach and ANT fertilise the LTS perspective set out from some of the points of criticism presented earlier in this section, e.g. the missing system user perspective.

Changing socio-technical systems

Technology and system studies departing from the described perspectives (the LTS approach in particular) primarily concentrate on describing historical processes of change rather than aiming for guidance on how to manage future policy-driven socio-technical change. Naturally, this has to do with the already mentioned fact that the bearers of the LTS tradition often are historians of technology. Moreover historical studies are often motivated by the fact that the study of past events and developments, leading to generalised conclusions, can help policy-makers to foresee similar future events and developments. However, the next step in this logical line of thought – how to create, guide or control future events and developments leaning on historical observations and generalisations – is seldom extensively elaborated in LTS studies. This observation should however not be stated as a general rule. In spite of the focus on narrative research elements followed up by retrospective conclusions, related discussions on future policy can be, and have been, done. Although somewhat sweeping, one example is Kaijser 1994, recommending a broad arsenal of means of control, due to the momentum and inertia of infrasystems, which often obstruct changes initiated from outside the system. Kaijser also highlights the importance of understanding the internal dynamics of the system, when aiming for changes with an external origin, e.g. the authorities' implementation of means of control. Moreover, when it comes to studies regarding contemporary systems that are subject to an intensive technological development, the future perspective usually is present due to obvious reasons. One example is the development of the Internet (e.g. Abbate 1994; Ilshammar 1998; Werle 1998).

In the following subsections some examples of change perspectives applied on socio-technical systems – all more or less related to the LTS approach – will be surveyed: changing large technical systems (Summerton 1994), the socio-technical toolbox (Kain 2003), the system innovation approach (Elzen et al. 2004), and shifting city-building regimes (Gullberg and Kaijser 2004).

Changing Large Technical Systems

In this context the anthology *Changing Large Technical Systems* (1994, edited by Jane Summerton) should be mentioned. This anthology provides a wide range of empirical studies of large technical systems in different contexts and regions. Part 1 of the anthology is on the topic of combining parts of systems, e.g. how railroads and information have affected warfare (Bucholz 1994). Part 2 provides examples of how systems can cross territorial borders, e.g. German telecommunications (Robischon 1994). The change perspective in part 3 concerns cultural incompatibilities and how they are confronted, e.g. compromises associated with the Internet (Abbate 1994). Although part 4 – "Controlling Car Traffic: Will the System Change?" – is future oriented, the over-all impression of the anthology leans towards the narrative and explanatory rather than the policy-oriented. Consequently, in my opinion, the title should be interpreted as 'LTS in change' or 'Processes of change of LTS', rather than 'How to change LTS'. It should however be noted that that is in line with the description and ambition stated in the introductory sections of the book.

The socio-technical toolbox of Kain

The fact that the LTS and SCOT approaches generally are oriented towards description and analysis rather than active change, is also recognised by Jaan-Henrik Kain in his dissertation *Sociotechnical Knowledge – An Operationalised Approach to Localised Infrastructure Planning and Sustainable Urban Development* (2003).

Departing from a socio-technical understanding of network change (e.g. Hughes 1983; Callon 1987; Bijker 1995; Guy et al. 2001), Kain develops a socio-technical toolbox, resulting in a conceptual model for local interaction in order to apply socio-technical thinking to concrete practical infrastructure management. Kain (2003) names the socio-technical toolbox SoTeK, and the conceptual model the MAIN^{tetra}. The MAIN^{tetra} is an image of thought shaped as a tetrahedron, with the dimensions *Mind*, *Artefact*, *Institution* and *Nature* in each corner (i.e. all dimensions are connected to each other). In the MAIN^{tetra} various indicators can be arranged and analysed, e.g. environmental, local economy, spatiality, robustness and social indicators. An elaboration of Kain's model (2003, pp. 325-335) ought to be a useful contribution to a not well-explored Mode 2 research field (Gibbons et al. 1994, see discussion in section 1.4), which could be named 'action-oriented research on local socio-technical systems'. The model of Kain (2003) will not be further elaborated in this thesis, but will however be discussed in relation to the SITOP concept in the synthesis in chapter 3.

System innovation and transition contexts

In the anthology *System Innovation and the Transition to Sustainability* (2004, edited by Boelie Elzen, Frank W. Geels, and Ken Green), a penetrating analysis of how socio-technical systems can change in a sustainable direction is presented. The concept of 'system' is not only limited to infrastructure systems, but also includes other systemic phenomena such as food supply.

The system innovation approach is partly inspired by the LTS tradition and other science and technology studies (STS) such as SCOT and ANT, but is also drawing on evolutionary economics (e.g. Nelson and Winter 1982), long-wave theory and techno-economic paradigms (TEP) (e.g. Freeman and Perez 1988), and on path dependency theories (e.g. David 1985, see also discussion on path dependency in section 2.4).

The theoretical point of departure of the anthology (in chapter 2, by Geels 2004) is that the protection of promising

- *technological*[4] *niches* (micro level: e.g. hydrogen cars or car-pooling), can eventually lead to shifts of the prevailing
- *socio-technical regimes* (meso level: e.g. transport activities, practices, rules and regulations), which in the end of the line might effect the
- *socio-technical landscapes* (macro level: e.g. physical infrastructure, urban structures and "widely shared cultural beliefs, symbols and values" (Geels 2004, p. 36)).

A *regime* can be defined as the set of arrangements that determine, control, or govern a certain phenomena or development (Elzen et al. 2004; Stone 1989). Generally a regime is considered as predominant phenomenon, or a state of things, however often associated with certain actors. A broader interpretation of the regime concept might also actually those include those actors (Gullberg and Kaijser 2004).

Drawing on Schot (1998), Geels (2004) argues that radical innovations are primarily generated in niches, while regimes rather generate incremental changes. This view coincides with Hughes' (1983) and Kaijser's (1994) notion of the conservative character of the outcome of the momentum in a strong system culture, in terms of how reverse salients are solved through conservative inventions. Although the protection of promising niches is promoted, the belief that the niches by definition are protected from normal market selection is however conveyed. One example of a naturally protected 'incubation room' for technical novelties is the military complex, which has stimulated radical innovations such as the digital computer, the jet engine and the radar.

Further on in the anthology, Berkhout et al. (2004) move the line of thought one step further – from 'strategic niche management', and 'transition management' (e.g. as described by Kemp et al. 1998), to the conditions determining regime shifts – by way of discussing four different 'transition contexts' (pp. 67-70):

[4] The concept of 'technology' is used in a broader sense compared with 'technique' or 'technical artecfact'. "Technologies in this sense are seen as being formed by, and embedded within, particular economic, social, cultural and institutional structures and systems of belief." (Berkout et al. 2004, p. 51).

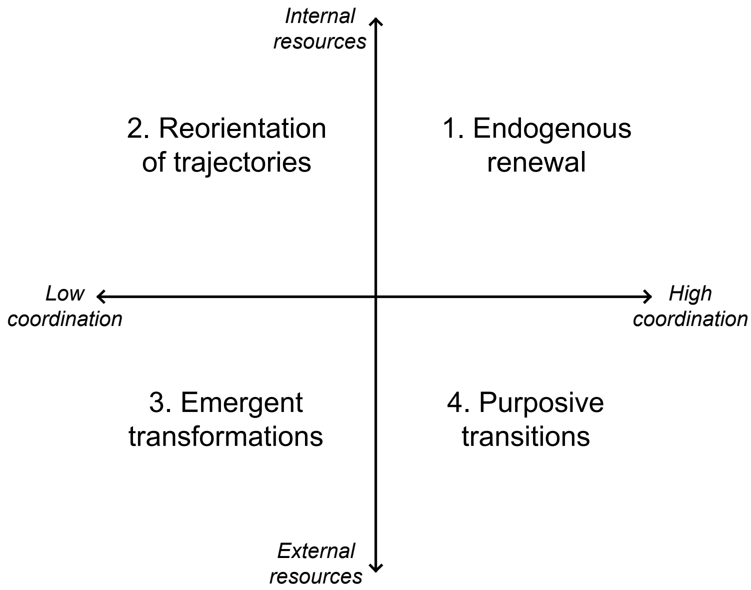

Figure 3. Four transition contexts and transformation processes (based on Figure 3.1 in Berkhout et al. 2004, p. 67).

Endogenous renewal [1] is characterised by high coordination changes via internal resources. Endogenous renewal emanates from conscious efforts of actors within the socio-technical regime (e.g. supply chains, system users, regulators) in order to meet threats against the regime (compare with *dynamic conservatism*, *momentum* and *system culture* in an infrasystem organisation managing *reverse salients* and *critical problems*). One example mentioned by Berkhout et al., is when oil dependent energy producers responded to the concerns over acid emissions by way of investing in desulphurisation facilities.

Reorientation of trajectories [2] is characterised by low coordination changes via internal resources. Drawing on Rosenberg (1994, pp. 216-217), Berkhout et al. (2004) highlight that in spite of the fact that some regimes have an intrinsic property of 'systemness' in their process of change, the development pattern can be "radically altered by internal processes without being associated with discontinuities in the actors, networks or institutions involved in the regime" (p. 69). One example is the large-scale adoption of combined cycle gas turbines in the British energy sector, which was neither intended nor anticipated but arose via a series of "uncoordinated technological opportunities, changes in market regulations and obstacles facing alternatives such as coal and nuclear generation" (ibid.).

Emergent transformations [3] are characterised by low coordination changes via external resources. Emergent transformations have an autonomous character. The origin of these transitions might be found in the major technological cycles – or 'long waves' – formed by complex economic and social processes. One example can be the seemingly inevitable transition from wood, through coal, to oil as primary fuels in the energy sector (compare with *radical changes* of an infrasystem in the stagnation phase).

Purposive transitions [4] are characterised by high coordination changes via external resources. Purposive transitions are distinguished from emergent transformations in the sense that they are at least partly intended and pursued, and the pressure of change is mainly located outside the regimes, generally from governments or influential public authorities such as the military. One example is the development of nuclear (power) technology in the mid 20th century.

The four different 'transition contexts' of Berkhout et al. (2004) constitute a conceptual framework of how to understand and analyse a process of change concerning socio-technical regimes. However, Berkhout et al. point out that further theory elaboration, and empirical testing, is needed in order to gain proper utility.

The empirical contributions in the anthology (Elzen et al. 2004) concern for example the Dutch gas system (Correljé and Verbong 2004), and the Swiss agri-food chain (Belz 2004). Moving from the theoretical points of departure concerning niches and transitions, through the empirical material, the anthology ends up in a discussion on transition policy and ultimately, inducing transitions by way of stimulating learning through experiments and niches, and stimulating breakthroughs of novelties cultivated in niches. Elzen et al. (2004) conclude that "a slight bend can lead to drastically different outcomes in the longer run which, after all, is what transitions are about" (p. 288). Elzen et al. (2004) partly associate their approach with Yale political economist Charles Lindblom's 'muddling through' (1959; see also Lindblom and Woodhouse 1993), which in brief is a concept that sums up the notion of incrementalism in policy-making. However, Elzen et al. (2004) add that "understanding the dynamics of development allows one to identify opportunities for intervention and specify how such interventions can be productive" (p. 288).

The concept of 'muddling through' will be further elaborated in relation to the SITOP concept in section 2.4. The conclusions of Elzen et al. (2004) will also be further discussed in the synthesis in chapter 3, when addressing situations of opportunity for infrasystem change in a sustainable direction.

The shift of City-Building regimes

Partly oriented towards explaining 'status quo', and partly explaining change, this approach – *City-Building Regimes* (CBR), introduced by Anders Gullberg and Arne Kaijser (2004) – combines elements from LTS and Urban Regime Theory (URT).

One of the aims of the CBR approach is to explain how "a mess of divergent processes taking place on different levels can result in relatively stable stages in urbanization", but also to "explain the shifts between such stable stages" (Gullberg and Kaijser 2004, p. 15). By a city-building regime Gullberg and Kaijser mean "the *set of actors* and the *configuration of coordinating mechanisms* among them, which produce the *major changes in the landscapes of building and networks* in a specific city region at a given time" (p. 18). Gullberg and Kaijser suggest an approach to systematise and analyse possible actor configurations by way of addressing the following distinctions (p. 19):

- Public or private actors?
- The geographic base – actors pertaining the actual city, or the suburban municipalities?
- Actor classification based on roles or function, e.g. political decision-makers, planners, investors, infrasystem operators, property owners, commercial companies, unions, associations of tenants, etc.

Drawing on Thue (1995) and Larsson (1991), Gullberg and Kaijser continue with the classification of the coordinating mechanisms:

- *Markets* – 'the invisible hand' (of Adam Smith, 1776)
- *Hierarchies* – 'the visible hand' (Chandler 1977)
- *Networks* – 'the handshake' (Larsson 1991)

The main hypothesis of Gullberg and Kaijser (2004) is that homogenous periods in a city development – in other words recurrent and similar changes in the landscapes of buildings and networks – “can be explained by the prevalence of a stable CBR, in which a certain set of actors have developed efficient forms for cooperation in certain kinds of projects, which they repeat over and over again” (p. 19). This hypothesis might have consequences for the actor perspective of SITOP, which will be discussed in the synthesis in chapter 3.

Based on a case study of the development of post-war Stockholm, Gullberg and Kaijser (2004) point out some variables on three different levels which can affect the stability of a CBR when changed, i.e. inducing regime shifts. Consequently, these aspects are also important to consider when it comes to maintaining a stable city-building regime (p. 35-36):

- *Local level* – the geo-political conditions, e.g. the level of independence of municipalities, the political and geographical possibilities to expand the city and to establish inter-municipal infrastructure (e.g. subways).
- *National level* – government policies and parliamentary decisions, e.g. subsidies for housing and transport, and the legal foundations for physical planning.
- *International level* – availability of technologies at different times, e.g. for building houses, and also transport, energy and IT technologies.

The CBR model of Gullberg and Kaijser (2004) will be further discussed in relation to the SITOP concept in the synthesis in chapter 3.

Concluding comment

To sum up, infrasystems are here seen as socio-technical systems. Therefore, changing infrasystems in line with sustainable development are regarded as socio-technical processes of change. The LTS approach primarily concentrates on describing historical processes of change rather than aiming for guidance on how to manage future policy-driven socio-technical change. However, the system innovation approach and the CBR approach, both partly based on the fundamentals of LTS, take it a couple of steps further.

One of the most significant common features in LTS, SCOT, CBR, the system innovation approach and the other conceptual views brought up in this chapter is that engineering and technical fixes is only one part of the solution. In the epilogue of *Networks of Power*, Hughes illustrates this conclusion, and catches the essence of the socio-technical change perspective, by way of using yet another metaphor from the field of physics (1983, p. 465):

> "Attempting to reform technology without systematically taking into account the shaping context and the intricacies of internal dynamics may well be futile. If only the technical components of a system are changed, they may snap back into their earlier shape like charged particles in a strong electromagnetic field. The field also must be attended to; values may need to be changed, institutions reformed, or legislation recast."

However, Hughes' conclusion does not elaborate the answers of the important questions: Change and reform by *whom*, and ultimately *when*?

2.4 Situations of opportunity and Fields of options – a perspective on change

The principal change perspective used and elaborated in this cover essay is the concept of *situations of opportunity* (SITOP). SITOP will be used to facilitate the elaboration of the questions stated above – infrasystem change when, and by whom? Furthermore the aim is also to contribute to the theoretical development of SITOP, which is a research task included in the doctoral project, which is accounted for in this cover essay.

The *field of options* is a concept related to *situations of opportunity*, mirroring the level of freedom of action for the concerned actors. The principal view of SITOP is that the possibility to implement changes, in order to gain environmental improvements, is greater than average at certain moments in time.

The approach of analysing situations of opportunity and fields of options should be considered a draft theory, or a research strategy 'under construction', which is elaborated in the MAMMUT research programme (MAMMUT = Managing the Metabolism of Urbanisation; Svane 2005a). However, the SITOP concept obviously relates to established concepts and views such as *formative moments*, *windows of* *opportunity*, *policy windows*, *determinism*, *rationality*, *muddling through*, and *path dependency* (each elaborated in following sections). As mentioned earlier, one of the aims in this cover essay is to discuss the theoretical framework of SITOP in relation to infrasystems, but also to contribute to SITOP's methodological development.

It is safe to say, that the temporal aspect and the change orientation perspective play a more apparent role in the SITOP concept, compared with the LTS perspective – the point of departure that *the possibility to implement changes is greater than average at certain moments in time*, and that *the normative goal of change is environmental improvements*, are key features of the SITOP concept. Other differences, similarities and synergies between SITOP and the socio-technical systems perspectives (primarily LTS), are further discussed in the synthesis in chapter 3.

The MAMMUT approach in brief

Identifying and analysing situations of opportunity, and their fields of option, is a core feature in the methodological and conceptual framework of the research programme MAMMUT – Managing the Metabolism of Urbanisation. The overall aim of the programme is to analyse relations and positive synergies between the processes of urbanisation and sustainable development. The research theme includes a number of case studies and also theory and method development projects (of which this cover essay is one example), involving researchers from several institutions, mainly at the Royal Institute of Technology in Stockholm.

The link between urbanisation and sustainable development is approached by way of considering the questions (elaborated in Svane 2005a and 2006; and Weingaertner 2005):

- *What can be changed?*
- *By whom is change guided?*
- *When can conclusive change best take place?*
- *How much – which is the possible extent of change?*

It can be useful to approach the notion of change in a somewhat over-explicit manner, since the MAMMUT theme covers complex areas including many actors and institutions, various physical structures, debated policy areas, and also external factors and developments which the actors in question are unable to control. In the *process of change*, the *object of change*, answers the first question – *what?* The *agent of change* answers to the question – *by whom?*

Urbanisation leads to changes in cities, including objects such as urban infrasystems and conditions of how to establish, operate and regulate infrasystems in urban areas. Naturally, system builders and infrasystem service providers, can only to a certain degree create and reshape the conditions of their own activities – agents of change (*by whom?*) do not alone determine the outcome of the process of change, resulting in altered objects of change (*what?*).

The focus in this thesis is not limited to urban infrasystems only. However, in a broad sense this thesis' focus – infrasystem change in a sustainable direction – can easily be related to changes caused by, or prerequisites for, the urbanisation process, briefly discussed below.

In the context of urbanisation, a situation of opportunity can be analysed departing from various perspectives. Changes affect physical structures (i.e. buildings and infrastructure), government, authorities, private enterprises, people's ways of life and the environment. In the MAMMUT approach, the questions stated above – *What? By whom? When?* and *How much?* – are central. In her licentiate thesis, Carina Weingaertner (2005) structures the potential array of answers to the questions into the following categories:[5]

- the structural aspect,
- the institutional aspect,
- the social aspect, and
- the environmental aspect.

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[5] Some differences regarding approaches to find answers to the questions *What? Whom? When?* and *How much?* should be pointed out. While the first three questions naturally enough direct to qualitative analysis, the fourth question might require some kind of quantitative assessment. The MAMMUT approach states that the contrast between factual and counter-factual developments – the 'field of plausible outcomes' – should be analysed from an environmental perspective (however, the structural, institutional and social aspects can also be analysed). If environmental aspects are to be considered in a non-trivial manner, the field of options should somehow be mirrored via quantified comparisons, at least in terms of comparable magnitudes.

Weingaertner (2005, p. 37) names the dimensions "the four aspects of urbanization". Weingaertner calls attention to that "in order to understand the process of urbanization and how it relates to sustainable development not only the four aspects themselves as separate entities are relevant, but equally important are the relations and synergies between these aspects" (ibid.). Referring to three pilot studies, Weingaertner concludes that the relations between the four aspects have the character of *mutual dependency* or *interchange*, rather than *cause-effect*. The relationship between the four aspects, and the LTS perspective, will be further discussed in chapter 3.

Let us return to the key concepts of the SITOP approach. A situation of opportunity consists of:

- a prehistory,
- a formative moment, and
- an outcome.

The field of options represents the range of freedom of choice in a decision-making situation. The outcome of a situation of opportunity can be derived from, or found within, the *field of options* of each situation. The extreme choices in the field of options create a span delimiting – or showing the directions of where to find – plausible future outcomes. The field of options in future situations of opportunity can be explored by way of using scenarios (which will be discussed further on in this chapter). When it comes to analysing historical situations, plausible counterfactual developments, combined with the actual observed development, define the historical field of options for a certain situation. When studying a specific past decision-making situation, 'plausible counterfactual' outcomes might for example be other suggestions that were on the table at the time, or solutions implemented in other cities or countries at approximately the same period of time.

In the following sections perspectives on formative moments, the prehistory and field of options (in relation to the SITOP concept) will be elaborated. Affinities with related theories will be addressed. Also the actor perspective of SITOP will be discussed.

Formative moments and related concepts

SITOP is a broader concept than the concept of *formative moment*, originally established by political scientist Bo Rothstein (1992 and 1996). The formative moment can be interpreted as the climax of a certain situation of opportunity. In Rothstein's concept a formative moment is induced by a specific problem or crisis which existing political institutions are unable to handle. The change perspective is limited to institutional and political aspects, surrounded by new economic and social circumstances.[6] Formative moments are, in Rothstein's definition, reserved for political actors:

> "If political systems are usually tightly structured by institutions, changes can only occur at certain times. It is only during such formative moments that political actors are able to change the institutional parameters or the nature of the "game". These formative moments of political history are distinguished by the fact that existing political institutions are so incapacitated as to be unable to handle a new situation (Krasner 1984). In such situations, political actors not only play the game: they can also change the rules of the game." (Rothstein 1996, p. 159)

The general meaning of formative moments is often slightly broader than the original concept of Rothstein. A broad interpretation is that a formative moment is a situation where it is possible to make decisions in different directions (Sundström 2001). However, when the decision is made, it will have long-term effects and influence future decisions (Pierson 1996). The concept has also been used to explain the

[6] Rothstein (1992) originally introduced the concept of formative moments to explain the importance of certain political decisions in Sweden during the depression in the early 1930s. Rothstein especially highlights the formative moment of June 1932, when the Swedish, at the time liberal, government (with support from the Conservative and the Centre parties) advocated compulsorily organisation, de facto a collectivisation, of the Swedish farmers, in order to prevent price dumping of milk. This regulation was carried through in spite of the fact that it was going against traditional liberal ideology. However, the agricultural regulation of 1932 became a precedent, which later opened up the door for the Social Democrats to pursue compulsorily enrolments of workers in unions (in the emergency agreement, 'krisuppgörelsen', of 1933), in order to strengthen the Labour Movement in general, and to eliminate the occurrence of strike-breakers and blacklegs in particular. Rothstein claims that the formative moment of 1932 enabled the process of forming 20th Century Sweden into a society characterised by collectivism rather than liberal individualism, and in the field of economic policy, maintaining the rates of wages and the purchasing power rather than allowing structural changes induced by a unregulated markets. (Rothstein 1992, chapter 6.)

shaping of individual, collective and national identity (Möller 2000), which sometimes could be a contributing reason to why states go to war (Ringmar 1996), i.e. going to war could be a formative moment.[7]

One way to identify a historical formative moment is to seek for plausible counterfactual outcomes, i.e. show that different decisions could have been made. This is a view that very well coincides with the SITOP approach, when it comes to making fields of options visible.

The notion of formative moments has several points in common with other policy- and decision-oriented concepts. A short digression is made below with the purpose to summarise three other related concepts (as described in an overview of institutional change in Brikell 2005):

- Ellinor Ostrom's (1990 and 1999) *action arenas*, or *situations*, has similarities with formative moments and situations of opportunity, however the immediate context – i.e. cultural differences and formal and informal rules regulating the situation – is regarded more important than the timing.
- *Policy windows*, elaborated by John W. Kingdon (1995), comprise short periods of time when the concerned actors have opportunity to implement new policy. A change of political leadership, changes in power relations in an assembly, or a significant shift in public opinion usually opens a policy window. Compared with situations of opportunity, Kingdon's concept is more downright policy-oriented.
- *Windows of opportunity* is a well-known concept used in various contexts, even in everyday speech. Sociologist Peter Townsend describes in Becker (1991) [ed.] windows of opportunities as recurrent situations when a specific policy agenda is possible to promote. Some other developers of this school of thoughts are Bachrach and Baratz (1970) and Lukes (1974), arguing that new policy is possible to implement in certain situations, but not in other situations, "because the full extent of the consequences of that policy trend is not realised among those that are affected in a negative manner" (Brikell

[7] However, a formative moment (according to Ringmar's definition) does not have to be a war, but could also be other periods characterised by strong collective identity: "Formative moments, we could say, are characteristically periods of symbolic hyper-inflation – times when new emblems, flags, dress codes, fetes and rituals are continuously invented." (Ringmar 1996, p. 85).

2005, p. 18). The concept of windows of opportunity is much less constricted in time, compared with policy windows and formative moments. Also the cyclical trend of windows of opportunity is often highlighted, i.e. the windows associated with certain issues should not be considered as one-time occasions – they tend to open up recurrently.

To sum up, in the SITOP concept the notion of formative moments is used in a broader sense compared with the original meaning of Rothstein (1992). Besides focusing on institutional and political aspects, the structural and physical aspects are also considered, and the specific problems or crises (of Rothstein), threatening existing political institutions, are not considered essential to induce a formative moment. Another important difference between Rothstein's formative moments and the SITOP concept is the view upon the goal of change. Roughly speaking, Rothstein elaborates the possibilities for certain actors to obtain political power, or changing the political system. The SITOP approach is oriented towards goal rationality in terms of environmental improvements, more or less regardless of who is controlling the political institutions. Moreover, the role of the prehistory, preceding the formative moment, is highlighted in the SITOP approach.

Prehistory – determinism or not?

Every situation of opportunity, or formative moment for that matter, has got a prehistory. In some cases, the preceding planning process or a decision-making process and its ingredients in terms of e.g. altering institutions, power relations and public opinion might very well mirror a situations' prehistory. The extent of such a prehistory might be a couple of decades or so. However, some institutions, or institutional traditions, are long-lived and not very susceptible for change. Many institutions rest on foundations established many decades ago. When it comes to the physical structures of society, such as infrastructure and buildings, the lack of fast changes goes without saying. Therefore, every situation is subjected to a certain degree of history dependency. In a specific situation of opportunity the field of options is always limited by its prehistory. But how wide can we expect the field of options to be? History matters, but how much?

Svane and Weingaertner (2006) place the SITOP concept in between *determinism* and *formal rationality*. SITOP also relates to the concept of *muddling through*, which at some levels coincides with the notion of *path dependence*. A run-through of these concepts is presented below.

The philosophical doctrine of *determinism* can be summarised as follows: every event is the inevitable result of previous causes; or, every state of affairs, including every human event, act, and decision is the consequence of antecedent states of affairs. It is, however, not uncontroversial to state that future events have already been determined as a result of past actions, since that usually implies a denial of the free will of human beings. When it comes to human behaviour, e.g. in ethical or psychological contexts, 'soft determinism' (introduced by William James, 1884) can roughly be described as a compromise acknowledging free will, however the will is determined by underlying motives.

Roughly speaking, *rationality* means that the search by people for the optimum decides the choices they make. In a political context, John W. Kingdon (1995, pp. 77-78) interprets the notion of rationality as a three-step procedure:

> "If policy makers were operating according to a rational, comprehensive model, they would first define their goals rather clearly and set the levels of achievement of those goals that would satisfy them. Then they would canvass many (ideally, all) alternatives that might achieve these goals. They would compare the alternatives systematically, assessing their costs and benefits, and then they would choose the alternatives that would achieve their goals at the least cost."

However, Kingdon emphasises the fact that the rationality model "does not very accurately describe reality" (1995, p. 78).

Among economists, the concept of 'homo economicus', or 'economic man', often comes to personify the concept of rationality (although its relevance and application is often questioned): human beings are rational and will always try to maximise their utility in terms of money or other gains. Another angle of approach comes with the 'rationality theorem', introduced by political scientist Graham Allison, stating that "[t]here exists no pattern of activity for which an imaginative analyst cannot write a large number of objective functions such that the pattern of activity maximizes each function" (Allison and Zelikow 1999, p. 26; originally from Allison 1971).

Formal rationality is a broader form of rationality that characterises activities of (bureaucratic) organisations. In essence, the concept has evolved from the works of German sociologist Max Weber. In formal rationality, the significance of rules, regulations, and larger social structures is highlighted rather than the values and choices of individuals. In the context of SITOP, Svane and Weingaertner's interpretation is that formal rationality implies "that once a goal is well defined, it is possible to apply rationally chosen actions to attain that goal" (2006, p. 1).

Muddling through is a concept that sums up the notion of incrementalism, introduced by Yale political economist Charles Lindblom in his article *The Science of Muddling Through* (1959)[8], also referred to in relation to the system innovation approach (section 2.3). The concept does not take position on the philosophical scale discussed earlier – whether or not the phenomena of 'free will' exists – where rationality and hard determinism are the extremes. Lindblom described the reality of decision-making as incremental processes, rather than as isolated rational choices. Lindblom's purpose was not to promote any approach, however he explained why the rational approach sometimes fails. The essence of muddling through is that small steps, i.e. a series of minor changes, when aiming for policy changes, generally produces more successful results compared with the implementation of single major moves. Lindblom argued that there is a high risk associated with solving complex problems with radical changes since the outcome is difficult to evaluate.[9]

On the topic of guiding the process of urbanisation and sustainable development, Svane and Weingaertner (2006) discuss Lindblom's concept and state that "the

[8] By the term 'muddling through', Lindblom probably alludes to the British expression 'muddling through somehow', referring to the metaphor of the British bureaucratic decision-making process as a muddle, however, still getting the job done. The contradictory title – 'science' vs. 'muddle' – should be seen in the context of the time (1959) when the article was written. The late 1950s was the golden era of rationalism, followed by a strong belief that scientific approaches such as technical analysis and optimisation would form successful policy. (Interpretations of Lindblom's motives in Chilton 2003: *Rationality Vs. "Muddling Through"*).

[9] In *A Model of Muddling Through*, Jonathan Bendor (1995) elaborates Lindblom's risk reasoning by way of addressing *evaluative risk* (as described by Lindblom) on the one hand, and *lottery risk*, on the other hand. Lottery risk can be defined as a situation when the policy-maker knows the risk – i.e. the outcomes are known (which is not the case with evaluative risk situations) – but still has the possibility to reject change by way of cancel or postpone actions, i.e. sticking with status quo.

decision-making process is an incremental one, and that decisions are consequences of a historical record of previous choices" (p. 2). However, they also stress that the SITOP concept is goal-oriented (i.e. leaning towards rationality) and highlight the rare situations where the possibility to change is greater than average, i.e. when 'muddling through' is bypassed. The role of Lindblom's concept in the SITOP approach is that 'muddling through' generally mirrors everyday policy-making and implementation and thus the prehistory of a situation of opportunity, however the mechanisms associated with the rare emergences of situations of opportunity operate on a more strategic level. Svane and Weingaertner (2006, p. 2) state that "we agree that past events and existing knowledge influence decisions as well as decision-makers, but we assume that, at least to some extent, it is possible to guide the process of urbanization".

Another related concept, the notion of *path dependency* is neither an approach of how to implement policy, nor a contribution to the philosophical 'free will' debate. Path dependency is rather a model of explanation leaning towards determinism, representing the view that change depends on its own past. Path dependence is a term that is used in a wide range of academic fields, from simple statements that 'history matters', through applications in complex mathematic models of specific process or situations (Greener 2002)[10]. The concept is considered to have its roots in the work of Veblen (1915) explaining why the economic development in the UK was overtaken by Germany during the decades preceding World War I (Arrow 2000). However, the theory was later elaborated by economists in order to explain technology adoption processes and industrial evolution. The theory has had a strong influence on evolutionary economics (e.g. Nelson and Winter 1982), with the approximate meaning that path dependence exists when the outcome of a process depends on its past history, on the entire sequence of decisions made and resulting outcomes, and not just on contemporary conditions. A modern example of path dependency – described by much cited Paul David (1985) – is the survival of the

[10] In the context of understanding socio-technical organisation, the article *Theorising path dependency: how history come to matter in organisations?* by Ian Greener is an interesting contribution relating to Actor Network Theory (ANT). Greener combines the path dependence concept with an approach to organisational analysis based around ANT, with the purpose to "[...] better understand the processes by which organisations become "locked-in" to behaviour patterns, but also how we might begin to break free from them" (quote from the abstract of Greener 2002).

standard keyboard layout QWERTY in the digital era. QWERTY was originally developed to avoid jamming in mechanical typewriters, a reason which became irrelevant when modern computer keyboards replaced their mechanical counterparts.

To sum up, the SITOP approach partly acknowledges the thoughts of Lindblom (1959), since the prehistory associated with a situation of opportunity, probably is best reflected by the notion of muddling through; "we take a middle way between the assumed full rationality of economic man and the near-deterministic muddling through" (Svane 2006, p. 2). If muddling through is predominant over time in a specific decision-making context, and a formative moment is arising but not utilised, a *lost opportunity* will be rendered.

Svane (2006) also associates the prehistory – in terms of extent and character – to an 'early warning system', which could be an actor network with the purpose to identify potential future situations of opportunity. Premonitions indicating that a situation might be on the way increase the possibility to utilise the opportunity, since it might take time to identify the field of options and to involve the actors of concern. The actor perspective of SITOP will be elaborated further on in this chapter.

Field of options

A formative moment can be regarded as the climax of a decision-making process, a series of decisions associated with alternatives and actor combinations, enjoying certain freedom of choice, which equals the *field of options*. As mentioned earlier, to define the field of options of a historical situation of opportunity, the factual outcome can be combined with alternative developments associated with counterfactual outcomes (Svane 2005a; Weingaertner 2005). In the MAMMUT approach, focusing on urbanisation and sustainable development, the outcomes can be described in terms of altered infrastructures and buildings, new institutions, environmental effects and changes in inhabitants' everyday life. One of the purposes of the MAMMUT approach is to learn how to identify future situations of opportunity and how to widen the field of options for actors guiding urbanisation and sustainable development (Svane 2005a).

The field of options of a future situation of opportunity can be illustrated via scenarios of plausible alternative developments. Scenarios are used and often referred to in various academic contexts. Using scenarios to analyse and define fields of options, however, probably demands a distinct meaning of, and also a clear distinction between, various scenario approaches. Börjeson et al. (2006) present a scenario typology and divide the different approaches into:

- Predictive scenarios – *what will happen?* (forecasts and 'what if?'-scenarios).
- Explorative scenarios – *what could happen?* (external and strategic scenarios).
- Normative scenarios – *how can a specific target be reached?* (preserving and transforming scenarios).

When it comes to analysing and defining certain fields of options, normative scenarios should constitute the context rather than the tool. If the leading goal is sustainable development (as in the MAMMUT approach), normative scenarios, or images of the future, can answer questions such as *How could a certain city, in the year 2050, that meets the demands of sustainable development be arranged and look like?* Explorative scenarios might be used, on the one hand, to analyse long-term resulting effects of decisions made by the actors of concern, and on the other hand to identify and analyse developments beyond the actor's control. In essence, explorative scenarios are the scenario type most suited in the process of defining fields of options. However, also predictive scenarios can be of use, but principally in the context of assessing the plausibility of certain described fields of options.

Figure 4 below, used in various MAMMUT contexts, can be used to illustrate the differences between the normative and explorative dimensions in the SITOP concept. The end scenario, or the image of the future ("able to sustain"), is concretising the normative, while the series of situations of opportunity can be concretised in explorative scenarios, i.e. exploring the available – and plausible – field of options for each situation.

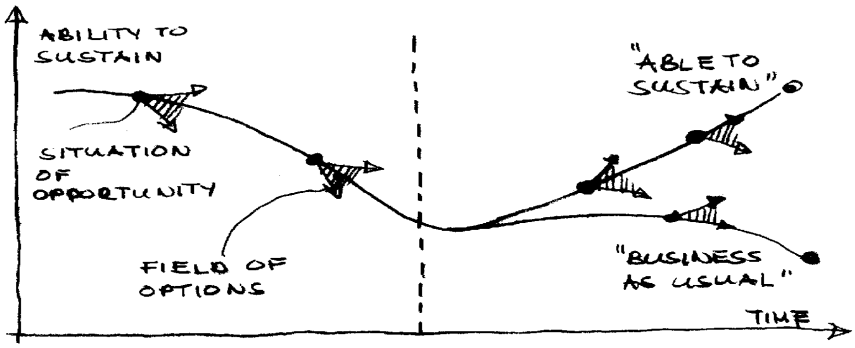

Figure 4. The ability to sustain as a function of time. In situations of opportunity, the field of options for the stakeholders is larger than average. In the figure a sustainable future scenario – "able to sustain" – contrasts with the "business as usual" one. (Svane 2006).

The strategy promoted in the MAMMUT approach, in order to utilise the field of options at its maximum, when aiming to achieve changes in a certain policy area, is to combine *necessities* with *desirabilities*. It is a question of reaching synergies between *what must be done* and *what should be done*. Since desires generally are subjective and normative by nature, the standpoints of *what must be done* and *what should be done* must be defined by mainstream policy and public opinion when it comes to public decision-making. Otherwise the dividing line between *necessities* and *desirabilities* will be irrelevant.

Anyhow, one example of combining *what must be done* with *what should be done* could be to utilise urgent renovations of the built environment to implement energy saving facilities and environmental friendly service solutions at the same time. Other more infrasystem related examples, e.g. utilising waste heat, or co-ordinating links of grid-based urban infrasystems, are discussed in paper 1 in this thesis.

The field of options varies over time and varies for different actors, however, alliances can taken together widen it. The implementation of changes that are not acute, though considered relevant in the long run, can be facilitated and brought forward when the promoters form alliances with advocates for necessary changes. Of course, defining measures that should be considered as necessities is determined by prevailing values and normative prioritisations, as discussed above. Promoters of desired changes considered as special interests, must accept that the necessary changes are defined by mainstream policy, or by such simple things as technical maintenance problems that 'need' to be solved.

Alliances pursuing certain changes, however with separate basic interests, can be considered as social innovations (elaborated in paper 2 in this thesis). One historical example was when parties with interest in various fields such as fire service, healthcare and insurance pushed through the construction of the water system in Stockholm during the mid-nineteenth Century (Jonsson et al. 2000).

It is obvious that common strategies can originate from different goals. For example, reducing private motoring in cities in favour of increased cycling can be pursued by environmentalists (to reduce emissions and save the nature), public health care (to reduce costs caused by fatness and heart conditions), neighbourhood communities (to reduce noise), police and rescue services (to reduce costs due to traffic control and accidents), city council and representatives of commerce (to decrease congestion which, among other things, facilitates transports of goods), cycling sports associations (to recruit new members), etc, etc.

However, when considering a sole actor, it is important to note that the character of the field of options changes over time. There is always a field of options present. During everyday operation the continuous field of options through ownership, general responsibilities and political mandates, is however limited. One of the main purposes of the SITOP concept is to establish a way of thinking that liberates policy-makers from the notion of how limited the means of change are. The key issue is that the possibility to implement change is not constant over time – everyday decision-making ('muddling through') has to be separated from situations of opportunity. Consequently, the changeover, widening the field of options – characterising a situation of opportunity – must of course be noted, if it is to be utilised.

In order to increase the chances that those rare opportunities will be utilised, Weingaertner (2005) highlights the role of researchers. She promotes the view that researchers should try to identify and define possible future situations of opportunity and then conveying this knowledge to the actors of concern. Moreover, Elfors (2006, p. 27) states that: "the chances of using a formative moment as a Situation of Opportunity are probably larger if the stakeholders are well aware in advance that a formative moment is approaching". On the same topic, Svane (2006) promotes an ‘early warning system’ (as mentioned earlier) with the purpose to identify coming potential situations of opportunity. The ‘early warning system’ might be an actor network or project organisation or just about any arena where the concerned actors can meet. The activities in such an ‘early warning system’ are relevant to a situation’s prehistory, and the prehistory is – as established earlier – intimately associated with the field of options for the actors. Based on a case study of a recently built residential area in Stockholm (Hammarby Sjöstad), Svane (2005b) concludes that since the process of integrating the views of *what should be done* with the views of *what must be done* takes time, the prehistory must have a certain extension. Moreover, the desirabilities should not be brought up on table too late in the process, since the already established frameworks – suited to the necessities – might make it impossible to realise the former. In other words, early warning, i.e. a long prehistory, makes it possible to render a wide field of options – which brings up a question that has only been briefly touched upon so far: *field of options for whom?*

Change by whom? – The actor perspective of SITOP

Whether the issue at stake is environment, equity, equality, economic growth, integration, unemployment or other policy areas, attempting to manage a complex political reality is always a question of compromising and prioritising. Special interests are deemed to struggle with established majority views. Mainstream policy might swing sometimes, however, the momentum and inertia are firm and strong, and are generally susceptible to change only in small steps – except when rare formative moments arise. Moreover, there is the obvious difficulty to turn attention to long-term problems when the desks of policy-makers are loaded with acute short-term problems. This is indeed a muddle, and it would be naive to pursue that the sole purpose of future policy on how to guide urbanisation, or design future infrasystems for that matter, should be to reach a sustainable society. Considering the concept of sustainability as a process, or a development, rather than a state of things, might however facilitate the integration and implementation of changes in a sustainable direction in mainstream policy, since a *process* by definition consists of small steps rather than a, perhaps frightening, instant turnover. But who will pursue those changes? Who can be considered the principal *agent of change*?

The actor perspective in the SITOP concept is not particularly distinct, in terms of pointed out actors, due to obvious reasons. Since the context and the specific *object of change* could be of various characters, the actors of concern cannot be specified in a general discussion. In the research programme concerning sustainable city development (referred to in previous sections), Svane (2006) states that specifying the actors, or stakeholders, associated to a specific situation of opportunity is a research task, i.e. the actors are not obvious input variables: "From the stakeholder analysis of each Situation, we identify a unique team of stakeholders that could form a project organisation to utilize the opportunities of that Situation" (p. 5). Although the SITOP concept primarily leans towards the perspective of planners, policy-implementers, and policy-makers, the previous quote shows that the principal agents of change should be considered as actor networks rather than sole actors. Planners, policy-implementers, and policy-makers are however pointed out as important players; "the local authorities play a central role as coordinators" (ibid.). Moreover, the difference between the actor-network identified as the principal agent of change in a specific situation, and the continuous actor networks watching out for future situations (as described earlier), is pointed out. Svane (2006) continues; "Furthermore, we assume that there is a need for a long-lasting network of stakeholders with the role of "early warning system" to identify Situations and organize the project teams" (ibid.).

Although not explicitly stated, among the different policy paradigms, the SITOP concept cherishes *policy networks* (processes and networks), rather than the *classic steering paradigm* (top-down, command-and-control) or the *market model* (bottom-up) (division based on Geels et al. 2004, drawing on De Bruijn et al. 1993). The awareness that the cluster of public authorities is just one of many stakeholders is made clear. Consequently, the policy perspective of SITOP leans towards 'governance' rather than 'government'. The governance paradigm usually highlights policy networks, learning processes and the interaction between various societal groups (e.g. Kooiman 1993; Rhodes 1997; Kohler-Koch and Eising 2000; Van Heffen et al. 2000). But no matter how the informal, and maybe even occasional, actor networks, or any form of public-private co-operations, are constituted in the specific case, "[g]overnance theory identifies the local authorities as a main actor" (Svane 2006, p. 5).

The perspectives of actor networks – where policy-makers, policy-implementers and planners play important roles – pursuing change in a sustainable direction by way of utilising the fields of options associated with situations of opportunity, will be further elaborated in the synthesis in relation to *system builders* of the LTS approach, and *city-building* and *socio-technical regimes* of the CBR and the system innovation approaches respectively.

3. Synthesis: combining the theoretical perspectives

What characterises the approaches presented in sections 2.3 and 2.4? What are the principal differences and common features of the socio-technical systems perspective, manifested by the LTS approach, and the change perspective described in the MAMMUT approach – with the situations of opportunity and field of options as main features? The purpose of the synthesis is to discuss the possibilities to combine a policy-oriented change perspective, based on the SITOP approach, with the discussed socio-technical systems perspectives. Ultimately, when are infrasystems most susceptible for change? How can the field of options be widened? Where can situations of opportunity be found?

3.1 Differences, common features and synergies

First of all, roughly speaking, LTS is primarily a model of explanation, and SITOP is a draft, action-oriented concept, aiming to be an instrument of change. An LTS study often describes the establishment, organisational formation, and expansion of an infrasystem, propelled by the overall goal to secure the survival, and continuous expansion (or maintaining steady-state) of the system. Beyond the academic arenas, the change-oriented SITOP concept may become a supportive tool in policy-making contexts – to be activated at certain occasions in socio-technical developments. The general approach in the MAMMUT programme is aimed for guiding urbanisation and sustainable development. However, the SITOP application can be used in other contexts, e.g. infrasystem change.

The temporal perspectives of the two concepts differ, although they might overlap. LTS studies often focus on successful system establishments, rather than aspects on steady-state or changes on 'old' systems (although there are exceptions, some mentioned in the previous chapter). However, the evolution of an infrasystem in terms of phases of development – as described by Hughes (1983) and Kaijser (1994) – can of course also include situations of opportunity, which will be discussed further on.

A distinctive common feature of LTS and SITOP is the perspective that technology, institutions and actors should not be separated. Among the kindred socio-technical perspectives, this view is strongest in the actor-network approach. However, also in LTS, the seamless web of technical and social aspects is highlighted. This is a view closely related to Weingaertner's statement of how to approach the four aspects of urbanisation, within the MAMMUT framework (2005, p. 37): the structural, institutional, social and environmental aspects are relevant as separate entities, however, " [...] equally important are the relations and synergies between these aspects". While Weingaertner and Svane broaden the seamless web concept towards social and environmental issues and effects, Kaijser (with infrasystem orientation) includes legal aspects and highlights the significance of influential and potential system users in the establishing and expansion phases, e.g. the military or energy intensive industrial sectors, but also manufacturers of system equipment, e.g. ASEA (electricity system in Sweden) and LM Ericsson (telephone system in Sweden) (Kaijser 1994).

However, in spite of the fact that Kaijser and other LTS inspired researchers pursue the importance to consider 'soft' units of analysis (as well as technology) – such as economy, social and legal aspects, and organisations and institutions forming system cultures – the basic view comes from a slightly different angle compared with Svane and Weingaertner's four aspects of urbanisation (structural, institutional, social, and environmental). There is no clear dividing line, but while LTS points out the 'soft' aspects as *components in socio-technical systems* on the one hand – i.e. they should be included in the definition answering the question 'what is an infrasystem?' – and as *dynamic variables in the development of socio-technical systems* on the other hand, Svane and Weingaertner primarily address the 'soft' aspects in terms of *outcome of change*, or *objects and agents of change*.

When it comes to analysing the outcome of change, the socio-technical toolbox of Kain (2003) might fertilise the SITOP concept. Kain's conceptual model for local interaction, in order to apply socio-technical thinking to concrete practical infrastructure management, might be used to iteratively analyse the outcome of a situation of opportunity by way of using e.g. environmental, local economy, spatiality, robustness and social indicators. How this could be done in practice will, however, not be further elaborated in this thesis.

Another overlapping area of interest is the view upon concepts such as momentum, rationality, determinism, path dependence and inertia. The LTS tradition – where the notion of momentum, inducing strong system cultures, is important – slightly leans towards technological determinism. The SITOP concept also acknowledges the importance of the prehistory, the inertia of socio-technical processes, and the fact that everyday policy-making generally can be described as incremental changes, i.e. the concept of muddling through (elaborated in section 2.4). SITOP is however clearly goal orientated and promotes the view that at the rare occasions when a situation of opportunity arises, the generally continuous forces of muddling through can be bypassed. Timing is crucial and efforts should be assembled in specific situations of opportunity. However, the notion of situations of opportunity covers several contexts and time-scales – from great political decisions, e.g. major infrastructure investments, to small and individual choices in the everyday life, e.g. the use of specific domestic infrasystem services. In other words, both great formative moments and small incremental changes can be associated with the SITOP concept (see e.g. Svane 2002). Nevertheless, in this cover essay, and in the work of Svane and Weingaertner, the focus is primarily on situations with a 'strategic' character, whether they are 'strategic' for society as a whole, a certain organisation, or just a household.

The importance of understanding the dynamics of incremental changes and muddling through is also acknowledged in the partly LTS inspired system innovation approach by Elzen et al. (2004), which corresponds well with the views of SITOP: "[U]nderstanding the dynamics of development allows one to identify opportunities for intervention and specify how such interventions can be productive" (Elzen et al. 2004, p. 288). However, while the system innovation approach initially promotes the protection of promising technological niches but later on tends to rely on spontaneous process – i.e. in some sense acknowledging technological determinism – SITOP rather leans toward continuous guiding of the development in order to approach sustainability.

Path dependency is a variation of determinism that might be considered to be a common feature of the LTS and SITOP perspectives. However, neither Hughes or Kaijser, nor Svane and Weingaertner call special attention to the concept of path dependence (elaborated in section 2.4).

In relation to the discussion regarding determinism, the development phases of the LTS approach should also be commented. Although variations of the development of different technological systems are acknowledged in the LTS approach, there is a firm belief that every system goes through a number of predefined phases with specific characteristics, including varying vulnerability and susceptibility to change. This might be considered more deterministic than the view of Svane and Weingaertner, but is indeed in line with the SITOP concept, seeking for special situations of opportunity where change can be implemented with success, rather than obstinately promoting certain changes over a long period of time.

The LTS approach generally focus on the view of the system builder. The successful system, or at least the survival of the system, is the overall aim. But how can the socio-technical perspective in general, and elements of LTS in particular, be utilised in a wider policy-making context to a greater extent than just be a tool used to understand the dynamics of infrasystems? By way of returning to the LTS critique presented by Lena Ewertsson (2001) (summarised in section 2.3), the change-oriented questions *what? by whom? when?* and *how much?* – central to the MAMMUT / SITOP approach – will be used again. Ewertsson argues that the idea of reverse salients is problematic due to the one-sided focus on certain system builders. "*To whom* is it presumed to be a reverse salient? *What system* is perceived as being constrained in its expansion or progress by any particular reverse salient" (Ewertsson 2001, p. 369). To point out the difference between the perspectives regarding overall focus, the question *why?* has also been added to the compilation below, showing a comparison of the different dimensions of change of the LTS and SITOP perspectives.

	LTS	SITOP
– ***What?*** The object of change. What can, or should be changed?	The socio-technical system, or parts of it, e.g. technical or organisational components and arrangements.	Buildings, urban infrasystems, institutions, or people's way of life.
– ***Why?*** The objectives, or reasons, to implement change.	In order to secure the survival of the system, or to maintain expansion.	In order to gain environmental improvements, or to approach sustainability in a wider sense.
– ***By whom?*** The agent of change. Who will guide the process of change?	System builders, or infrasystem organisations.	Actor networks, planners, policy-makers and policy-implementers.
– ***When?*** The timing. When can, or should, conclusive change best take place?	When a problem needs to be solved.	When a formative moment arises.
– ***How much?*** The extent of change. How much change is desirable? How much change is possible?	As much as it takes to solve the problem.	As much as it takes to reach certain sustainability goals, alternatively, as far as possible in a sustainable direction.

Table 1: Comparison of the different dimensions of change of the LTS and SITOP perspectives.

Change by whom? – Comparing the different socio-technical views

Among the questions stated above, the question *by whom* needs to be further elaborated. Generally the dominant actor perspective of a typical LTS study is the one of the system builder, or the system organisation. Not quite that obvious, however the actor perspective of the SITOP approach leans towards the view of the planner, policy-implementer or the policy-maker, as discussed earlier. When addressing fields of options, concerning the role of infrasystems in a sustainable development, it might be fruitful to nuance the concept based upon the fact that perspectives vary – not only between LTS and SITOP, but to some extent also within the approaches. The field of options of a system builder, or an infrasystem organisation, naturally has a different character from the field of options of a planner or a policy-maker, due to their different spheres of influence. It is also a question of how the field of options is perceived, considering the blinders created by the momentum and a strong system culture, or by the specific governing culture for that matter. One example is how traffic congestion in cities generally is dealt with – building more road capacity rather than trying to manage the traffic flows. For system operators, sometimes just a second opinion or a dialogue with system users might open up perspectives, in other cases a paradigmatic shift are called for in order to widen the field of options. One example of the latter is mentioned in paper 2, when some American electricity producers re-defined their role – from electricity providers to service providers: The demand was increasing, however the producers no longer found interest in raising the volumes of production. Instead, they took action to ensure that the produced electricity would be used in an efficient manner. One of the most important incentives was to avoid to be forced to build up new and expensive additional production capacity. The producers supported energy-saving and energy-efficient innovations down the line and could share the profits with the consumers (von Weizsäcker et al. 1997).

Seen from the perspective of a system builder or an infrasystem organisation, problems also can be considered internal or external. Some threats and obstacles can also be solved or contained by means available within the socio-technical system, e.g. technical fixes that increase efficiency. However, some aspects are generally out of control, e.g. competition from new systems delivering improved services.

When it comes to the actor related perspectives discussed here and in the previous chapter, a confusing circumstance is the use of different terminologies. My interpretation is that when moving one level above separate entities, *socio-technical systems* (as used in the LTS approach) consist of technology and infrastructure, providers, users and other closely related actors. Moreover the definitions generally also include rules, regulations, economic conditions and common cultural elements (i.e. the system culture). The *socio-technical regimes* (as used in the system innovation approach) consist of activities, practices, rules and regulations. The *socio-technical landscapes* (as used in the system innovation approach) consist of physical infrastructure, economic conditions and cultural aspects. The *socio-technical actor networks*, identified as important players in the SITOP approach[11] consist of various actors of concern, e.g. local government, planners, construction companies, NGOs, infrasystem operators etc. Interweaving humans, culture and man-made practices and technology is a key feature in the described approaches, yet it complicates the task of mediating a clearly delimited actor perspective. One might even think that notions like the seamless web, or the non-human actor elements of ANT, do not particularly encourage such discussions. Nevertheless, the figure below is an attempt to facilitate such a discussion, using the notions of socio-technical systems, regimes, landscapes and actor networks. The figure is a result of my interpretations aiming to highlight various socio-technical concepts, but should probably not be seen as a map of how to understand the relations between the discussed perspectives.

[11] Actor networks, as used in Actor Network theory (ANT) however, could also consist of technical, natural (etc.) actor elements, as the distinction between 'hard' and 'soft' aspects and units is broken down in ANT.

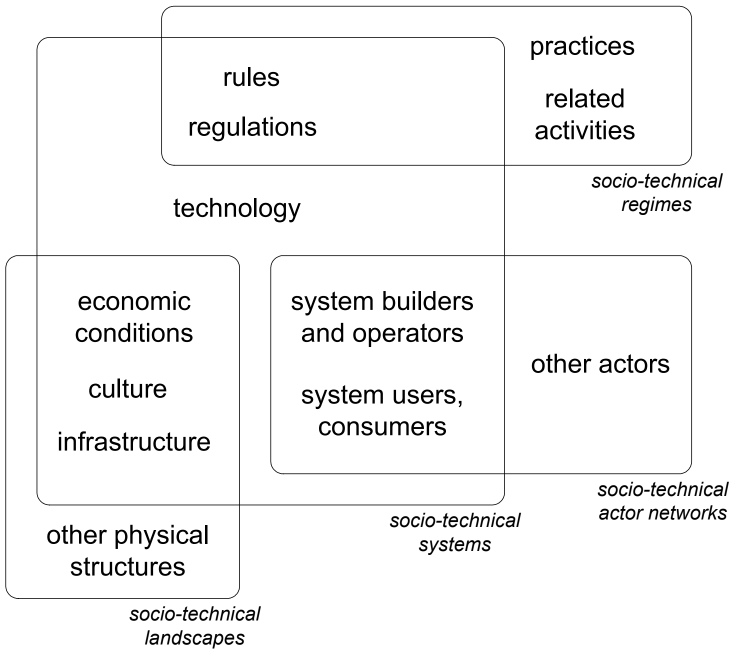

Figure 5. Comparing socio-technical views.

In this context also the city-building regime approach (CBR) of Gullberg and Kaijser (2004), introduced in section 2.3, will be revisited. CBR might contribute to the SITOP concept in general and, due to its focus on city development and urbanisation, to the MAMMUT research approach in particular.

One of the aims of the CBR approach is to explain how "a mess of divergent processes taking place on different levels can result in relatively stable stages in urbanization", but also to "explain the shifts between such stable stages" (Gullberg and Kaijser 2004, p. 15). By a city-building regime Gullberg and Kaijser mean "the *set of actors* and the *configuration of coordinating mechanisms* among them, which produce the *major changes in the landscapes of building and networks* in a specific city region at a given time" (p. 18). As described in section 2.3, Gullberg and Kaijser suggest an approach to systematise and analyse possible actor configurations by way of addressing distinctions such as the roles and affiliations, but also the geographic base. In the context of MAMMUT, the actor systematisation of Gullberg and Kaijser (2004) might be useful in the stakeholder analysis of SITOP, i.e. how to identify the socio-technical actor network associated with a certain situation of opportunity, or the "long-lasting network of stakeholders with the role of "early warning system" to identify Situations" (Svane 2006, p. 5).

The coordinating mechanisms of city-building regimes are addressed by Gullberg and Kaijser through the classification: *markets* ('the invisible hand'), *hierarchies* ('the visible hand'), and *networks* ('the handshake') (see section 2.3). Although the SITOP approach advocates *networks* when it comes to coordinating mechanisms – and also *policy networks* rather than the *classic steering paradigm* or the *market model* when it comes to policy paradigms (see section 2.4) – the view that the "local authorities play a central role as coordinators" (Svane 2006, p. 5) is also conveyed, i.e. leaning towards 'the visible hand'.

The main hypothesis of Gullberg and Kaijser (2004), is that homogenous periods in a city development "can be explained by the prevalence of a stable CBR, in which a certain set of actors have developed efficient forms for cooperation in certain kinds of projects, which they repeat over and over again" (p. 19). If considering this hypothesis to be true, and at the same time considering contemporary urban development to be unsustainable, it definitely has consequences for the actor perspective of SITOP. In order to utilise a situation of opportunity – in the context of change in a sustainable direction – the formation of a socio-technical network of influential actors is not enough. Whether it happens spontaneously or intentionally, the current CBR needs to face a breakdown, and a new stability with a new set of actors has to be re-established.

It seems safe to say that the shifts of city-building regimes are obvious situations of opportunity. But *when* do these shifts occur? And *when* can other situations of opportunity for infrasystem change arise?

3.2 Situations of opportunity for infrasystems

A shift of city-building regimes is not only a situation of opportunity to redirect the development of an urban area in general, but also to create new conditions for the future development of urban infrasystems. But before elaborating the discussion on regime shifts, let us go back a couple of steps – to the concepts of Rothstein, Hughes and Kaijser – in order to address the question of when there might be situations of opportunity to change individual infrasystems, rather than changing the development pattern of a city where many infrasystems are included.

Situations in different development phases of infrasystems

The notion of formative moments is a key feature of the SITOP concept, but can also easily be implemented in LTS flavoured discussions. Of course, the establishment of an infrasystem can be regarded as a formative moment, including the initial planning process, i.e. the prehistory, and the decision-making moment. One example investigated by Carina Weingaertner (2005) is the establishment of the subway in Stockholm as a situation of opportunity. The establishment of a new infrastructure can on the one hand be a question of choosing between alternatives (e.g. subway or motor boulevards), and on the other hand to manage and find synergies with other planning processes related to the main decision (e.g. building suburbs along the extension of a subway).

When returning to the original definition of Bo Rothstein, also other relations to the development phases of LTS can be made. Rothstein argues that formative moments are induced by specific problems or crises, leading the thought to Hughes' *reverse salients*, *critical problems* and *radical problems / changes*. According to Rothstein, if a situation should qualify as a formative moment, the existing institutions should be unable to handle the problems or crises. Hughes however, defines critical problems as problems solvable by (and within) the institutions concerned – i.e. by system builders or infrasystem organisations – thanks to a strong system culture and the momentum, facilitating the problem solving processes. However, the wider interpretation of formative moments (e.g. by Svane and Weingaertner 2006), allows the following systematisation of possible situations of opportunity in relation to the development phases of infrasystems (based on Kaijser's (1994) elaboration of Hughes (1983)):

Development phase of infrasystems	Situations of opportunity in the form of, or due to…
Establishment	Initial events: Invention, planning, and decision-making
Expansion	Expansion obstacles (generally internal): Reverse salients and critical problems
Stagnation	Threats against the system: Radical problems / changes

Table 2: Possible situations of opportunity in the different development phases of an infrasystem.

One example of when expansion obstacles can induce a situation of opportunity was referred to in the previous section (and in paper 2), when some American electricity producers supported energy-saving and energy-efficient innovations in order to avoid to be forced to build up new and expensive additional production capacity, also leading to environmental benefits. Another example (also previously discussed) can be to meet congestion and increased demand in the road transport system with differentiated pricing instead of expanding the road capacity.

The notion of radical changes in the stagnation phase differs from that of critical problems, which primarily are phenomena associated with the expansion phase. Radical changes threaten the existing order and the established institutions. One hypothetical example of a future situation of opportunity, allowing intervention of public actors, could be to support co-operations between actors representing different energy technologies in a situation of oil shortage. In other words promoting the combination of what must be done – decrease oil dependence – with what should be done – utilise renewable energy resources.

In an organisation vulnerable to radical problems, the momentum has become weaker and the earlier advantages as a result of a strong system culture may turn into a drawback characterised by conservatism and inability to adapt to the new situation.

This indeed opens up for true formative moments (also according to Rothstein's definition), and consequently, situations of opportunity. Radical problems, or changes, can arise due to competition from new systems, actors or services, shortage of raw materials, or be a consequence of new policy e.g. environmental legislation. In other words, the changed conditions usually originate from outside the system, in contrast to critical problems, which usually are consequences of reverse salients within the system (e.g. an institutional or technological component lagging behind the system's overall progress). It should also be noted that the notion of radical changes has several similarities with the regime shifts of the CBR concept.

A successful system with a strong system culture and momentum is generally not susceptible to change. Why change a winning concept? Problems are solved in a reactive manner, i.e. through so-called 'conservative inventions' (e.g. the introduction of catalytic converters in automobiles). However, the will to solve the problems when they eventually occur is certainly strong since the system's development is threatened. The policy-making perspective of the SITOP approach in the MAMMUT research programme rather has a proactive aim. Opportunities for change should be seized. With united efforts policy-makers, planners and system builders might contribute to great change, however, with differing objectives. It can be a question of combining *desired changes* with *necessary changes*. The road towards successful implementation of change does probably not allow widely differing interests, but if the solving of *reverse salients* and *critical problems* of infrasystems can be addressed in a co-operative manner, the implementation of environmental considerations also has a chance of succeeding. However, it is important to note that system builders, or infrasystem organisations, generally are capable of solving these kinds of problems on their own. Consequently, the co-operation must be associated with mutual gains. However, when it comes to threatening *radical problems / changes*, the bargaining room for interested parties outside the systems grows larger, since the infrasystem organisation is unable to handle these kinds of problems on their own.

With reference to the actor-oriented discussion in this section, it seems appropriate to repeat some of the critique of the LTS approach, elaborated in section 2.3. The synergies between the LTS and the SITOP approaches, when aiming for infrasystem change, is to some extent limited by the fact that LTS theories are coloured by the results of studies of successful establishments of investment intensive grid-based systems. Moreover, the studies generally concern only one system at the time. The strong focus on identifiable system builders and system cultures makes LTS more applicable on controllable and tightly coupled infrasystems such as electricity and railways, compared with loosely coupled systems such as road transports. However, just because the socio-technical mechanisms of some infrasystems are complex and hard to describe – and the actor relations are unclear and perhaps even variable – the LTS approach should not be rejected. Instead it should be developed. This has for example been done in the system innovation approach (Elzen et al. 2004) and the CBR approach (Gullberg and Kaijser 2004), but also by Blomkvist (2001) and Lundin (2003), addressing loosely coupled systems set out from an LTS perspective.

In many discussions in this cover essay, the perspective of the system builder / infrasystem organisation has been confronted with the perspective of the planner / policy-maker. It is however important to note that roles vary over time, and might even coincide. Moreover there are obvious differences between different sectors associated with infrasystems. When establishing a new infrasystem (e.g. a district heating system), or a new parts of a system (e.g. a motorway), i.e. in the investigatory, planning, decision-making, and building phases, there generally exists a co-operative arena for many of the actors of concern, e.g. planners, building companies and future operators, in the form of a project organisation responsible for the realisation of the system. When the system is up and running the project organisation is generally dissolved, and after that the organisational circumstances, as well as potential points of intervention between the actors, differ from system to system. Some systems are operated by well-defined private or public organisations also controlling the physical infrastructure, while other organisations operate on infrastructure owned by other actors. Some systems are loosely administered by public authorities and operated by a great numbers of actors. Conclusively, when seeking for co-operative arenas – which is an important feature in the SITOP approach in order to utilise situations of opportunity and to widen the field of options – it is important to note that when the establishing phase is over there probably can not be only one type of co-operation suggested for all infrasystems. Individual solutions for each sector are probably necessary, perhaps also for each kind of situation. This might result in the loss of overall perspective and weaken the forces striving for change, or regime shifts.

Regime shifts and transitions as situations

The stability of a city-building regime depends upon certain aspects, which can also be considered factors determining the conditions of change when it comes to regime shifts. The aspects of Gullberg and Kaijser (2004) (see also section 2.3) are divided into three different levels: *local* (geo-political conditions), *national* (government policies and parliamentary decisions), and *international* (e.g. availability of technologies at different times). The shift of city-building regimes might be induced at any of the levels above. Generally speaking however, the likelihood for situations of opportunity to come up via regime shift is probably at its greatest when changes at all levels occur at approximately the same time, i.e. when the prerequisites for the activities of the predominant CBR are being altered at many levels.

On the topic of regime shifts the conceptual framework of Berkhout et al. (2004) (within the framework of the system innovation approach) is also applicable in this context. The conditions determining socio-technical regime shifts is explained via four different 'transition contexts' (also in section 2.3):

1. *Endogenous renewal* – characterised by high coordination changes via internal resources.
2. *Reorientation of trajectories* – characterised by low coordination changes via internal resources.
3. *Emergent transformations* – characterised by low coordination changes via external resources.
4. *Purposive transitions* – characterised by high coordination changes via external resources.

Roughly speaking, transition contexts 1 and 2 primarily correspond to conceivable situations of opportunity considering internal system obstacles, e.g. the previously discussed reverse salients and critical problems. Transition context 3 generally implies that the actors of a socio-technical system or a city-building regime cannot control the conditions of the existing order, or maintain the stability of a CBR. This might correspond to the international level of the CBR approach of Gullberg and Kaijser (2004). Both transition context 3 and 4 can imply radical changes (if using LTS terminology). Transition context 4, purposive transitions, is the most relevant for SITOP, due to the goal- and policy-oriented features. Transition context 4 foremost corresponds to controllable, or at least manageable, aspects on the local and national levels, if using CBR terminology.

Situations concerning infrasystem users

The situations of opportunity and fields of options associated with systems builders, infrasystem organisations, socio-technical / city-building regimes, or planners and policy-makers all represent a fairly obvious top-down perspective, which is an inevitable result of the approaches used in this cover essay. However, at the other end of the spectrum, the system users (or consumers) can be found. In paper 2 of this thesis a system user perspective is discussed, but by no means fully elaborated. In spite of the fact that it is more or less beyond the scope of this synthesis, I think that a brief discussion on *situations of opportunity for infrasystem users* might be fruitful.

The field of options visible from the grass roots level is naturally limited to the available choices supplied by infrasystem service providers or society. However, most infrasystems connect to the built environment in various degrees, and the system users generally have some influence on the design and function of those interface points, especially in privately owned houses.

Drawing on two case studies, Susanna Elfors (2006) points out three categories of formative moments for a 'small neighbourhood' (i.e. a housing area, or a building, that is physically and administratively delimited), when the opportunity to implement measures for environmental sustainability is greater than average:

1. New construction
2. Refurbishment
3. Maintenance

Elfors labels the three categories as *physical measures*, but she also brings up a category of formative moments called *changed use*, which for example can be situations when a household moves from one flat to another or when an enterprise is reorganised. Moreover, ethnological and sociological studies show that individuals, or families, situated in certain crossroads of life are more susceptible to change than usually, i.e. it is easier to implement other changes as well at the same time (Andréasson 2000; Godskesen 2002; Henriksson 2004; Waldo 2002). The situations of opportunity might for example be when moving away from the parents, when beginning or ending working life, when starting a family, when the family grows, when getting a new job, or when moving to a new house or a new town. Moreover, these situations generally also affect the demand of services such as transportation and dwelling space in a direct manner. These occasions can be considered situations of opportunity not only for the users of infrasystems to implement environmentally friendly changes. They could also be potential opportunities for policy-makers to implement means of control affecting the life-style of people.

In the context of identifying situations of opportunity for infrasystem users, altered life-styles and activity patterns, how they can be affected, or how they might arise spontaneously, constitute an important but vast research field that is not theoretically supported in this thesis. Nevertheless, situations of opportunity for system users to substitute infrasystem services, and utilities, will be further discussed in section 4.2 (reflections on paper 2).

Summary

To conclude, the search for situations of opportunity in order to change infrasystems in a sustainable direction can be aimed at *reverse salients*, *critical problems*, and *radical problems / changes*. ‘What should be done’ should preferably be integrated with ‘what must be done’ within the framework of actor networks. The actor networks proposed by SITOP as the principal arena of co-operation in order to manage synergies between urbanisation and sustainable development (in a MAMMUT context), and to watch out for future formative moments (i.e. the ‘early warning system’), do generally not need to be designed in the establishing phase since they already exist in the form of project organisations. In the other development phases, there are generally no obvious arenas facilitating for example private and public co-operation. When designing such co-operative arenas, individual solutions for each sector are probably necessary, due to the differences regarding e.g.

actor set-ups and ownerships when the physical infrastructure is considered. Due to the vast spectrum of potential situations of opportunity – from global phenomena such as oil shortage, to local opportunities such as synergies when refurbishing houses – the associated actor network can, of course, not be stipulated as one static configuration. Each kind of situation probably requires a certain type of actor network.

On the higher level, the *shifts of socio-technical / city-building regimes* could be considered as situations of opportunity. Major changes in a sustainable direction probably presuppose new regimes with orientation towards environmental improvements and resource awareness. According to the CBR approach, old regimes will not be able to pursue the changes needed – the set of actors associated with the regime has to be altered. Among the transition contexts and processes described in the system innovation approach, the SITOP approach is primarily oriented towards *purposive transitions* on the local and national levels. Phenomena such as global trade patterns or the development of energy prices can in some cases be considered as circumstances, on the international level, maintaining regimes or other predominant orders also at lower levels, e.g. regimes prioritising automobile traffic in urban planning. Those circumstances are generally outside the sphere of influence for the local or national actors striving for change. Alterations on the international level can however entail situations of opportunity by way of affecting the conditions of change on the lower levels.

4. Reflections on papers

In this chapter the papers attached to the thesis will be commented in relation to the theoretical approaches developed in the previous chapters. In various ways, all papers concern how environmental effects of infrasystems can be reduced. This can be done in many ways, for example, changing the use of the systems, changing contemporary systems or replacing them with new systems, or to combine the planning of infrastructure in general with other measures reducing the environmental burden.

As stated in the introduction, the papers were originally not written with this thesis in mind, which of course affects the homogeneity of the thesis. Also some theoretical passages are repeated in the papers.

The purpose of this chapter is threefold. First, I will briefly describe the perspectives used when the papers were written. Secondly, I will add the perspectives elaborated in this cover essay, e.g. discuss fields of options and elaborate on potential situations of opportunity. Moreover, I will try to extract knowledge of a more general character from the papers, i.e. to supplement the synthesis in chapter 3 with findings from the papers, which however mainly will be accounted for in the concluding discussion of chapter 5.

The papers are titled as follows:

- Paper 1: Sustainable Infrasystem Synergies: A Conceptual Framework
- Paper 2: The Nature of Infrasystem Services
- Paper 3: Integrating Urban Infrastructures of Movement: A Vision of Sustainability
- Paper 4: Indirect effects to include in Strategic Environmental Assessments of transport infrastructure investments
- Paper 5: Indirect energy associated with Swedish road transports

In the following table, the scopes, basic outlooks, character, main result etc. of the papers are put together, in order to facilitate a comparison of the papers.

	Paper 1	*Paper 2*	*Paper 3*	*Paper 4*	*Paper 5*
Scope	Infrasystems in general	Infrasystems in general	Infrasystems, transport systems	Transport systems	Transport systems
Basic outlook	Technical	Socio-technical	Technical, socio-technical	Socio-technical	Technical
Character	Conceptual	Conceptual	Conceptual	Methodological	Result accounting
Leading actor perspective	System operators	System users	System builders, or operators	Policy-makers, planners	Policy-makers
Change via...	system synergies	social innovations, substitutions	coordination, integration, synergies	infrastructure planning, means of control	transport policy in general
Main result	Elaboration of infrasystem characteristics, defining synergy categories and linking them to characteristics.	A structural approach of how to understand infrasystem services via utilities and needs.	Discussion of coordinated urban transport systems, including conditions of introduction.	Key factors, in relation to indirect effects, to consider in environmental assessments.	A survey over the indirect energy associated with Swedish road transports.

Table 3: Comparison of papers 1-5.

4.1 Paper 1: Sustainable Infrasystem Synergies: A Conceptual Framework

The point of departure of Papers 1-3 is the conclusion of Jonsson et al. 2000, that infrasystems might be changed in a sustainable direction through

- system improvements,

- system synergies, or
- social innovations.

In paper 1 (published in *Journal of Urban Technology*, 2000), the focus is on system synergies.

The results of paper 1 can be divided into two main parts:

1. The conceptualisation of infrasystems in terms of networks, links, nodes, flows, and architecture, and a compilation of characteristics (including the introduction of new characteristics).
2. Categories of infrasystem synergies, and how the synergies relate to the characteristics.

The characterisation of infrasystems with components and systems parts as point of departure, rather than the services provided by the systems (e.g. energy, water or transports), is inspired by previous works of Arne Kaijser (mainly Kaijser 1994; however, also the works of Kaijser in Jonsson et al. 2000).

The synergy categories treated in paper 1 are;

- co-located links (of different systems),
- shared links (for the flows of different systems),
- common nodes belonging to systems with similar basic functions, and
- common nodes belonging to systems with different basic functions.

The leading actor perspective in paper 1 is definitely the one of the system operator. Paper 1 presents a number of synergy examples. The examples and the categorisation are aimed to support concerned actors in the process of finding opportunities to implement synergies.

Some situations in the development of infrasystems present greater opportunities than average to realise synergies. Those moments in time can be regarded as *situations of opportunity to implement synergies*. Using the terminology introduced in this cover essay, the overall purpose of paper 1 can be seen as to *visualise the field of options* for system operators, when it comes to imagining and realising infrasystem synergies. In other words, suggesting options for future situations of opportunity. However, all occasions when synergies can be implemented are not true situations of opportunity. Some possible synergies are simply unused, or unexplored, due to various reasons. However, they could be implemented at just about any time, e.g. utilising waste heat at easily accessible places in some infrasystems.

All the same, some synergy opportunities cannot be implemented at any time, mostly due to the fact that they have to be physically built into the technical structure of networks and components. If not utilised, they will be *opportunities lost*. At those situations, conscious planning and technical design at certain moments in time is necessary in order to realise the synergies. The section "Opportunities and Obstacles – The aspect of Timing" in paper 1, discusses the problems associated with the increasing sectorial specialisation, but also highlights an expected situation of opportunity for infrasystem synergies. Many urban infrasystem links in developed countries, primarily built in the 1950–60s, soon must be replaced or repaired in a large-scale manner demanding investments probably not seen since they where originally built. This circumstance offers situations of opportunity to implement synergies among the new or rehabilitated infrasystems that could be developed. If considering infrasystem synergies as a useful means for gaining environmental improvements, the described circumstances can indeed be characterised as a situation where *necessities* are combined with *desirabilities*, i.e. combining *what must be done* with *what should be done*. Another contemporary example, which might present situations of opportunity, is the development of various information infrasystems. New or improved IT services induce changes in all other infrasystems, mainly in order to rationalise operations, or to add services, perhaps considered necessary in order to stay competitive on the market. When those changes are implemented, there might be situations of opportunity to implement features entailing environmental gains as well.

In terms of new knowledge, the contributions in paper 1 I foremost wish to highlight is on the one hand the introduction of some new infrasystem characteristics – possibly pedagogical means to make future options visible in general terms – and on the other hand the structuralised synergy overview aiming to widen the field of options for system operators beyond present system boundaries.

4.2 Paper 2: The Nature of Infrasystem Services

While paper 1 focuses on change via system synergies, paper 2 (published in *Journal of Infrastructure Systems*, 2005) primarily addresses changes that go under the category of social innovations.

Social innovations can be described as the adoption of new ways of satisfying existing needs. On the one hand, social innovations can involve new ways for individuals, households, and enterprises to satisfy their needs, and on the other, new forms of organisation within the sphere of production and distribution (Gershuny 1983; Jonsson et al. 2000). New combinations of public and private activities, for example interplays between different actors, resulting in new ways to utilise infrasystems, or the establishment of new infrasystems, can also be regarded as social innovations (see examples in paper 2). Also new organisational solutions, with altered ownership relations, for example carpooling, can be considered as social innovations (for other examples: see paper 2).

However, the main focus in paper 2 is not to elaborate on the concept of social innovations. Social innovations set out from the need for services, and one way of stimulating the search for new social innovations is to address the underlying aspects of infrasystem services. The overall aim of paper 2 is to emphasise the need for a profound understanding of the nature of infrasystem services in the context of change in an environmentally sustainable direction. In paper 2 some perspectives on the concept of service are presented and a structural approach on how to understand infrasystem services via underlying needs and utilities (or conveniences) is outlined. A number of services (e.g. drinking water, public transport, electricity) provided by the infrasystems can of course be listed, and obviously an even greater amount (in total) of utilities and conveniences (e.g. cooking, getting to work, watching TV) associated with each service. However, the needs related to the services, utilities and conveniences have in paper 2 been limited to a limited number of household related categories, inspired by a similar division in Gullberg et al. 2006:

- Indoor climate
- Indoor hygiene
- Personal hygiene and health
- Food and drink

- Personal improvement and recreation
- Making a living
- Public services

Paying attention to services and utilities, rather than products and systems, has also been done by Elisabeth Shove (2004) (unfortunately not referred to in paper 2). The overall research question of Shove (2004) is how individual and collective conventions and habits can be broken by way of integrating services. Paper 2 aims to visualise potential substitutions by way of elaborating the character of the services – irrespective of conventions and habits.

In paper 2, the basic socio-technical outlook is more evident than in paper 1. In the introductory sections of paper 2 the socio-technical systems perspective is presented in brief (essentially based on Hughes 1983; Kaijser 1994; and Jonsson et al. 2000).

Having the SITOP concept in mind, a general dividing line between papers 1 and 2 can be identified. While the synergy discussion in paper 1 opens up the *field of options for system operators*, the elaboration of the link between services, utilities, and needs, in paper 2, rather put the focus on the *field of options for system users*, primarily individuals and households. In this context, the field of options is latent and wide, rather than defined through a certain situation.

One of the main purposes of exploring the link between services, utilities and conveniences, and needs, is to facilitate the search for new ways – preferably more environmentally friendly ways – to fulfil existing needs (in other words; social innovations). To fulfil a certain need (e.g. indoor climate), utilities (e.g. heating) produced by an infrasystem service (e.g. electricity), fulfilling that need might be entirely or partly substituted by other utilities (e.g. additional insulation of the house). Another conceivable substitution is when the original utility remains, however produced by way of using an alternative infrasystem service (e.g. heat from a district heating system), or a non-infrasystem related service (e.g. heat from a domestic bio-fuel boiler, or pulling on a sweater to compensate lowered indoor temperature).

Also the perspective on service via the underlying dimensions *volume*, *content*, and *quality*, as described in paper 2, is elaborated in the context of change. Service volume is the amount of what is delivered (e.g. kWh energy). Service content corresponds to the utility produced through the service (e.g. a certain indoor temperature). Service quality reflects reliability, accessibility, comfort or ease (e.g. lack of power failures). In the context of change aiming for environmental improvements, the relations between the additional service dimensions are important, since service volume often is intimately connected to the environmental burden related to an infrasystem, while service content and quality are associated with the utility and convenience produced through an infrasystem service. Measures to reduce environmental burden involving reduced service volume, but at the same time maintaining service content and quality, are easier to carry through compared to situations implying decreased content and quality, and consequently reduced utility and convenience.

In this context, the range of possible substitutions of services and utilities – and the possible decrease of service volume, however with maintained service content and quality, if a minimum of sacrifice is presupposed – constitutes the *field of options* for the concerned system users. Another aspect of interest is to consider how the field of options is perceived. To be able to maximise the field of options, established conventions of what is appropriate and possible might need to be challenged, e.g. imagining advantages gained from taking the bus to work in spite of the fact that no one else in the neighbourhood uses public transport.

Some substitutions, or changes, are easier to realise than others. A service related change, where the utility remains (as well as service content and quality), which does not imply any changes in life-style, or great changes in the built environment, seldom meets resistance (e.g. installing water saving WCs). However, when the change also presupposes altered activity patterns or changes in life-style, e.g. using public transport in order to get to work instead of the automobile, the resistance generally increases – in spite of the fact that the utility (in this case: getting to work) generally remains. It is naturally also harder to pursue changes, or substitutions, which presuppose larger technical or physical changes, due to additional costs and inconveniences, e.g. installing a new heating system – in spite of the fact that the utility (e.g. maintaining indoor climate) remains.

A question that must be asked in this context is of course if there are certain moments in time when the possibility to implement changes is greater than average. In other words, where can the *situations of opportunity* be found?

When it comes to changes implying altered life-styles, or activity patterns, the ethnological and sociological studies referred to in section 3.2 show that individuals or families situated in certain cross-roads of life are more susceptible to change than at other times, i.e. it is easier to implement other changes as well at the same time (Andréasson 2000; Godskesen 2002; Henriksson 2004; Waldo 2002). As described in section 3.2, the situations of opportunity might for example be when beginning or ending working life, when starting a family, when getting a new job, or when moving to a new house or a new town.

When it comes to changes implying alterations in the built environment, some of the situations of opportunity pointed out by Elfors (2006), as described in section 3.2, can be considered; new construction, refurbishment, and maintenance. Naturally, new construction is a great situation of opportunity to implement more environmentally friendly infrasystem solutions, but also to plan and build the house in a way that minimises the service volume, preferably without compromising with the needs. When refurbishing or maintaining, the field of options is more limited.

In this section, situations of opportunity and fields of options related to changes and substitutions of infrasystem services, utilities and conveniences have been discussed. But why not approach the needs? Can the needs be changed, substituted or eliminated? How can the conditions of change, concerning human needs, be stipulated? These are of course interesting questions, however I considered them to be beyond the scope of paper 2 and this cover essay, and also beyond my competence range. Nevertheless, I find it necessary to further comment the need categories used in paper 2 (also listed earlier in this section):

It is easy to establish that the need categorisation used in paper 2 constitutes a special case. They are indeed chosen to illustrate the typical conditions of contemporary everyday life in the Western World. Some categories are of course more universally applicable than others, e.g. 'food and drink'. However, people suffering from poverty, lack of food and clean water, or even having trouble finding a roof over their heads at night, might find need categories such as 'personal improvement and recreation' completely irrelevant. The hierarchy of needs of Abraham Maslow (1954), used in paper 2, might facilitate an elaborated discussion on this theme (which however, will not be done in this cover essay). Nevertheless, the lack of general applicability regarding aspects such as different ways of life, long-term development, and socio-economic conditions can of course be considered as a problem in an academic context (such as in this thesis). Although, in the context of sustainable development, I consider it safe to say that the contemporary ways of life lived by the propertied classes in the industrialised parts of the world, generally imply greater environmental impacts compared with the ways of life lived by people placed under poorer circumstances, or, for that matter, by the people who lived before the industrial revolution and welfare society.

To sum up, the most important contribution from paper 2 is actually the approach itself; to emphasise the benefits from infrasystem services, i.e. utilities and conveniences fulfilling needs, rather than using certain systems, actors or technologies as point of departure of an analysis aiming for environmental improvements. One of the results is shown in table 1 in paper 2, mirroring possible substitutions preferably without compromising the basic needs, i.e. widening the field of options.

4.3 Paper 3: Integrating Urban Infrastructures of Movement: A Vision of Sustainability

Paper 3 was published in the anthology *Moving People, Goods, and Information in the 21st Century: The Cutting-Edge Infrastructures of Networked Cities* (2004, edited by Richard Hanley). Paper 3 can be seen as a transport oriented continuation of paper 1. Synergies and co-ordinations of infrasystems in the context of sustainable development are highlighted and two examples of coordinated transport systems are elaborated; dual-mode systems for personal transport, and transports of goods with home delivery based on e-commerce. By way of conclusion, the conditions for introduction of new infrasystems in general, and the transport systems dealt with in particular, are discussed.

Paper 3 is at large parts based on earlier publications. Parts of the introductory and conclusive sections about sustainable development, infrasystems, synergies and system coordination are based on paper 1. The transport system solutions dealt with are elaborated from Jonsson et al. 2000, Jonsson 1998, and Steen et al. 1997.

Moreover, the discussion about conditions for introducing new transport systems is based on Jonsson et al. 2000, and Steen et al. 1997.

In terms of system synergies, integration and co-ordination, paper 3 is primarily oriented towards the establishment of new system concepts – by way of co-ordinating existing system solutions – rather than seeking synergies by way of integrating low-level system parts, which was given great attention in paper 1. Consequently, possible situations of opportunity associated with the elaborated examples primarily have the characteristics associated with establishments of new systems.

The described dual-mode system for personal transport is based on the advantages of large-scale public transport (rail-bound connected coaches) but uses the automobile as a model for design, so as not to compromise the attractive features of the personal vehicle, e.g. flexibility and privacy. A dual-mode system can be considered a combination of an electric automobile and a genuine rail vehicle. The combination of electric car flexibility and rail system range can make the dual-mode system an interesting alternative for personal transport in urban areas, especially since the system can be established gradually.

A *situation of opportunity to introduce a dual-mode system*, or any other new transport system for that matter, could be when growing cities experience traffic congestion. A problem that needs to be solved generally opens up for a wider array of suggestions, compared with the average situation. In such situations however, the political arena generally is dominated by two standpoints of how to solve the problem (as in Stockholm of today, i.e. 2006):

1. Build more roads – preferably ring roads.
2. Expand and make public transport more attractive, and limit automobile traffic.

The parties concerned agree upon that there is a problem, however the solutions differ. The strength of this situation of opportunity (seen from the perspective of the promoters of the dual-mode system) lies in the fact that the dual-mode system combines the advantages of private and public transport, i.e. there could be a good chance to attract representatives from both political camps. However, it is always easier – and less risky – to invest in well-tried solutions, i.e. roads and conventional public transport. Consequently, the advantages of the dual-mode system would probably have to be proven before leading to large-scale investments. In terms of infrastructure, the dual-mode system can be established gradually, since the existing road network is supposed to be utilised, which is a great advantage. However, when considering other technological system parts, especially the necessary development of new types of vehicles constitutes a great obstruction.

The introduction of a dual-mode system is thus primarily a question of introducing new technology. When considering the home delivery system, the importance of the socio-technical aspects of change is more evident.

In a sustainability context, a home delivery system based on e-commerce primarily aims for a transition from automobile dependent purchase trips to dedicated delivery rounds, also including garbage collection. On the technical system level, reloading and transhipment terminals (or split centres) integrated with waste management centres – which can be considered as nodes in a new infrasystem – must be established.

It is not obvious who could be considered to be the leading actor of an expanded home delivery system. Since the proposed system solution could concern many actors – including those from traditional infrasystems – some sort of joint venture, perhaps guided by local authorities, is likely. However, since it already today is possible to order everyday commodities for home delivery over the Internet, the chains of stores offering these services today of course have an advantage.

When considering the location of stores offering everyday commodities, the trend in many European countries is to establish great shopping centres in the periphery of urban areas, associated with the risk of driving similar services in the city centres out of business (e.g. Hagson 2003). In connection to the shopping centres, great areas intended for parking make them accessible, however not for everyone. A *situation of opportunity to establish a large-scale home delivery system* might depend upon the ratio of automobile ownership of city dwellers. The external shopping centre trend – often promoted by local authorities – combined with the decrease of centrally located stores, might create a profitable market constituted by city dwellers not owning an automobile. However, this chain of thought probably only results in a system fulfilling a limited niche, not leading to any environmental improvements since it presupposes the effects of external shopping centres, inducing even more automobile traffic.

To conclude, neither the dual-mode system, nor the home delivery system can be associated with spontaneously arisen, strong situations of opportunity. The conditions determining the possible realisation of these kinds of transport-oriented novelties, or system solutions, are probably better to analyse within the framework of the system innovation approach (see e.g. section 2.3), rather than in a SITOP context. How this might take place in practice, regarding niche management and transforming socio-technical regimes, will however not be further elaborated here. Nevertheless, a cautious conclusion might be that the realisation of obvious environmental improvements as a result a new urban transport techniques probably requires an active and purposeful traffic policy – not only by way of protecting promising niches, but also by way of using regulations and various means of control.

4.4 Paper 4: Indirect effects to include in Strategic Environmental Assessments of transport infrastructure investments

Paper 4 (published in *Transport Reviews*, 2006) is about indirect effects of transport infrastructure investments. Indirect effects are important to consider when making consequence analyses and environmental assessments of potential transport solutions and infrastructure plans. The primary objective of paper 4 is to emphasise the need of a deeper understanding of the long-term system effects of investments in transport infrastructure with a focus on the structuring effects that roads and railways have on society, for example altered transport patterns, or altered settlement structures. Special attention is given to the following potential indirect effects:

- increased total transport volume,
- increased share of private motorists and truck transport,
- increased urban sprawl, and,
- increased energy use in the built environment.

In paper 4, the conditions that determine the outcome are discussed and a number of key factors to be considered in transport infrastructure planning, particularly in strategic environmental assessments, are suggested.

The overview of papers in the introduction of this chapter (table 3), shows that paper 4 has a different character as compared with paper 1-3. Paper 4 has a one-sided focus on transport systems and has a clear methodological aim, namely to contribute to the development of Strategic Environmental Assessments (SEAs) of transport infrastructure.

The area of interest in paper 4 is planning processes involving investments in transport infrastructure, whether the question is to establish new infrastructures or adding parts to existing networks. Consequently, the *situation of opportunity* is given. The design of infrastructure and its decision-making processes must be considered situations of opportunity with long-term implications, which not only influence future travel patterns and settlement structures, but also can induce changes in the organisation of people's everyday life. Seen from the perspective of planners and policy-makers associated with a specific infrastructure project, the possible alternatives of how to fulfil the suppressed transport need in question constitute the *field of options*. For other policy-makers, influential actors, and other concerned parties situated in the periphery of the relevant decision-making, an infrastructure planning process can also be considered a situation of opportunity, since it usually is easier to promote other measures or investments as well, when the change window is open. For those stakeholders however, the field of options is generally limited by the agenda stated by the actors controlling the main process. The situation of opportunity for those stakeholders might rather be characterised by the possibility to suggest measures with the purpose to mitigate potential negative effects. However, if these measures are smartly designed, preferably in a progressive manner, the outcome can in the long run – at least in theory – result in decreased environmental impact in total.

Concerning road infrastructure, the official policy in Sweden of how to solve accessibility problems should formally follow the so-called 'Four-stage Principle'. If the problem can not be solved by measures of the first step, step two should be consulted, and so on (Swedish National Road Administration 2002):

1. Measures affecting the demand for transport and the choice of mode of transport.
2. Measures that give more efficient utilisation of the existing road network.
3. Road improvement measures.
4. New investment and major rebuilding measures.

It is safe to say that the field of options is at its greatest in step 1, since most means of control, and co-ordinations or substitutions also concerning other modes of transport still are on the playing board. However, the field of options shrinks drastically from 1 to 2. Step 2-4 are limited to measures concerning road networks only. In spite of the official policy, some studies show that in the end of the planning process, the measures proposed generally are step 3 or 4 measures (e.g. Jonsson 2004b).

To conclude, the field of options associated with the situation of opportunity for planners, policy-makers and policy-implementers – intimately connected to the process of solving a specific accessibility problem (according to the 'Four-step Principle' above) – is in theory relatively great. For other actors of concern, e.g. other authorities, organisation and interest groups to which a proposal might be submitted for consideration, the field of options is limited by the preliminary decision already made.

However, if bending a little bit on the SITOP definition, a situation of opportunity of a different character – for transport oriented planners and researchers – can be identified in this context. The need to include indirect effects in transport infrastructure appraisals has been widely recognised, e.g. in a manual for strategic environmental assessments of infrastructure plans issued by the European Commission (directorate for energy and transportation) (2001), but at present no methodology has reached the status of a wide spread standardised procedure. The development of practice and methodology dealing with indirect effects is still in an explorative phase, admitting a situation of opportunity for researchers and planners to influence the mode of procedure of future infrastructure appraisals.

4.5 Paper 5: Indirect energy associated with Swedish road transports

Paper 5 (submitted to *European Journal of Transport and Infrastructure Research*) deals with indirect energy associated with road transports. Besides energy for propulsion – through the consumption of gasoline, diesel or other fuels – other energy categories, considered as indirect, are addressed as well:

- Infrastructure: construction, operation, maintenance, and deconstruction

- Vehicles: manufacturing, service, and scrapping
- Fuel production

The data used in paper 5 is based on a number of transport energy studies (see paper 5, p. 2). Combined with Swedish statistics, the processed data is used to estimate the amount and shares of the indirect energy associated with Swedish road transports. The share of indirect energy is calculated to slightly more than 45%, specified as;

- 22% infrastructure energy,
- 14% vehicle energy, and
- 9% fuel production energy.

The main manifesto of paper 5 is to highlight the significance of indirect energy. This insight should have implication on decision-making processes concerning infrastructure, and also be an aspect to consider when designing means of control aiming for the reduction of energy use in the transport sector.

In paper 5 the calculation model is also used to perform a coarse test of the impact of some hypothetical energy reduction scenarios by way of altering separate variables. The lesson learned is that isolated separate measures may not have the intended impact, due to indirect energy. For example, a fifty percent reduction of fuel consumption for cars – thanks to improved efficiency – may only lead to a 25 % reduction in total, when the entire road transport sector, including infrastructure and vehicle production, are considered. Such an example illustrates the magnitude of the challenge involved in radically reducing transport energy use.

Paper 5 differs from the other papers attached to this thesis and has the character of quantitative result accounting. The change perspective although present, is oriented towards *effects of change*, rather than conditions, or possibilities, of change. Paper 5 does not link any specific *situations of opportunity*, however the approach used illustrates a way to assess *field of options* available for policy-makers, in terms of energy and environmental aspects. Referring to the SITOP concept, the approach used in paper 5 might contribute to processes evaluating the guiding question *how much?* – not only in terms of the possible extent of change in practice, but also the extent of change needed to satisfy a sustainable development.

5. Concluding discussion

As stated in the introduction, the papers attached to this thesis were written independently of the cover essay. The principal research objects in the papers are infrasystems or transport systems, while the main focus in the cover essay is the processes of change associated with the systems. The main purpose of this concluding chapter is to supplement the synthesis in chapter 3 with findings from the papers. I will however start in the other end of the line, and briefly discuss how the papers might contribute to the field of infrasystem and transport research – independently of the SITOP concept.

Generally speaking, I consider the foremost contribution to be conceptual knowledge. This has been achieved through the elaboration of perspectives of how to understand infrasystems, and also through supplementing the collection of theoretical concepts and characteristics in this field of research – however, not only to satisfy the small crowd of academic researchers who are into infrasystem terminology. The conceptual views and designations might be used as tools to visualise what otherwise would not be seen – and the question that must follow is of course 'seen in what context?'. One simplified answer could be; 'in the next step of the analysis'. When elaborating, one can come to the conclusion that the process of dealing with the environmental problems associated with infrasystems must start with problem awareness. What is the problem? How grave is the problem? After that the normative and plausible outcome of change might be addressed. What should change result in? What is possible? What aspects determine the conditions of change? The 'next step' is of course to identify solutions. What options are there? By way of using alternative approaches to find solutions (papers 1 and 2), or to consider infrasystems as an interrelated entity of society rather than in divided sectors (paper 1), or to seek new perspectives by way of addressing services and utilities rather than systems, actors or technology (paper 2), or to consider new systemic solutions rather than improving existing ones (paper 3), might increase the number of conceivable solutions. In other words, it might *widen the field of options*. Moreover, there is a need to assess the options (paper 4), not only in terms of environmental indicators such as energy use (paper 5), but also through how the interplaying features of infrastructure, buildings and human activities affect other sectors of society and the environment (paper 4). In other words, *evaluating the field of options*.

Let us return to the main purpose of this section in the thesis – to supplement the synthesis in chapter 3. One situation of opportunity described in paper 1, associated with the fact that many urban infrasystem links in developed countries soon need to be replaced or repaired in a large-scale manner, lead the thought back to the development phases of Hughes (1983) and Kaijser (1994). One of the drawbacks of the LTS perspective, also brought up in the critique discussion in section 2.3, is the preferred focus on first time establishments of successful systems and their growth, sometimes neglecting the most frequent condition of an infrasystem, namely 'steady-state'. The development phases of Hughes (1983) are first of all invention and development, then technology transfer, and after that an unnamed expansion phase characterised by technological momentum. The development phases of Kaijser (1994), frequently used in this cover essay, are establishment, expansion, and stagnation. If 'steady-state', which is closely related to Kaijser's 'stagnation', also implies that infrasystems are not continuously maintained in a customary fashion, there seem to be certain periods in their development demanding massive investments and reconstruction in order to secure future survival. If the future shows this to be a recurrent phase, rather than an isolated case due to special conditions in the second half of the 20th century, it indicates a development pattern of a different character compared with the views promoted by Hughes and Kaijser. A recurrent *rebuilding phase* mirrors a cyclic development pattern, rather than the classic S-curve of development, sometimes used by historians of technology, and historians of economy.

A key feature of paper 2 is to highlight *services* – and the *utilities* and *conveniences* produced through the services – rather than systems, technology or certain actors associated to that specific technology. The common focus of LTS – on technical core and on system builders, rather than on function – is questioned also by Ingelstam (2002). By way of moving the perspective from the conventional physical and organisational structures to function and utility, a different set of concerned parties may become the centre of attention. Figuratively speaking, the many features of an infrasystem service, including potential utilities and conveniences, surround the arena where stakeholders should be able to meet in order to expand and add their fields of options together, and to find situations of opportunity. The common denominator is the multi-dimensional character of the service. At least when considering small-scale examples, e.g. a small community sharing a water resource associated with various utilities (irrigation, drinking water, cooling, washing, cleaning, boat traffic, fishing etc), the arena to facilitate the search for situations of opportunity is imaginable.

The discussion on paper 3 is related to earlier discussions in this cover essay conveying that in spite of different agendas, actors can manage to create a common view upon a certain problem, thus identifying situations of opportunity. They agree that the problem exists, and they agree that the problem needs to be solved. However, the proposed solutions might lead to completely different developments and effects. In the discussion on paper 3, a combination of private and public transport elements was proposed to reduce congestion in urban areas. A frequent view is that congestion simply should be considered as a *reverse salient* in the road transport system, i.e. congestion is a result of lack of road capacity, which can be fixed with more roads. However, problems in loosely coupled systems with a non-centralised character do not always seem to respond well to exclusively internal measures. Urban transport does not only concern road builders but also city-planners, politicians, housing enterprises, commerce and the people that live and work in cities. Moreover, increased capacity can in some cases aggravate a reverse salient, due to the lack of a comprehensive view.[12] A broader approach, involving many actors of concern, to solve the problem is favourable, and the first prerequisite for being able to utilise the situation of opportunity is to create a common problem formulation.

Another example of a problem to which a number of solutions in different directions have been proposed, is climate change and global warming. A solution also

[12] According to the Downs-Thomson paradox (Downs 1962; Thomson 1977) new roads initially mean less congestion, however as the automobile gains popularity, some former passengers of public transit will switch to the private alternative. Decreased demand for public transport services and reduced profits mean higher prices, lower level of service quality and reduced frequency of services. In other words, loyal passengers of public transport stand to loose from road construction, and private motorists will accept even worse congestion before switching back to public transport. In the end, congestion becomes worse on the roads at the same time as public transport deteriorates.

moderating conflicts in order to break the political deadlock is certainly preferable. If I allow myself to speculate, a conceivable solution aiming for the reduction CO_2 emissions might be considerable investments in bio-fuels and nuclear power, and at the same time implementation of distinct and purposeful measures to use energy more efficiently. An integrated solution of this kind, concentrates both on supply and on demand by way of combining suggestions from the entire political scale.

Public planning and decision-making processes concerning infrastructure are given extra attention in the reflections on papers 3 and 4. It is worth repeating that these processes are of course true situations of opportunity. Problems associated with the sectorisation of society in general, and infrastructure planning in particular, are discussed in relation to papers 1 and 4, e.g. different authorities managing the planning of different modes of transport. Applying the terminology proposed in this cover essay, one might maintain that *sectorisation reduces the field of options*, if not for the concerned planners and decision-makers, who in most cases already are sectorised, then at least for society as a whole. If the public planning and decision-making processes are wrongly designed (considering the risks of sectorisation), they will automatically render *lost opportunities*.

When having the notions of formative moments and muddling through in mind, the run-through of the papers might lead to the conclusion that the establishment, or change, of some systems generally are characterised by large projects at certain situations, while changes on some other systems rather have an incremental character. The character of change differs from system to system, but is however also determined by the specific problem inducing change, the system's current phase of development, and the aggregation level associated with the change (in terms of local, regional, national or international system changes). Papers 3-5 might indicate that changes in mature infrasystems with a loosely coupled character, such as road transports, generally have an incremental character. If this means that the SITOP concept is less applicable in practice, I do not know. But I guess that the possibilities for co-ordinated interventions in a SITOP manner is greater when the *object of change* is easy to identify and delimit, which for example might not be the case when considering the hundreds of simultaneously ongoing small road building, or improvement, projects in Sweden.

The lack of ability to visualise the available field of options, considering sectorised infrasystem organisations characterised by a strong system culture and technological momentum, has more or less been taken for granted in several contexts in this cover essay. If this notion is exaggerated, it becomes a dangerous preconceived idea delimiting the possibilities for actors to find the rare co-operative arenas necessary in order to widen the field of options and to utilise situations of opportunity. As indicated in section 2.4, various scenario approaches might contribute to the process of visualising the field of options, indeed also for the individual actor. For separate organisations, explorative scenarios can, besides raising the perspective beyond their own activities, also contribute to the widening of the field of options. Besides, normative scenarios – with transforming and preserving elements combined – can facilitate the understanding of how to manage the co-existence of different goals, no matter whether the goals have an internal or external origin. For example, 'the survival and growth of our business', combined with 'environmental goals established by the Government'. It is, once again, a question of finding and utilising situations of opportunity in order to combine desirabilities with necessities. Anyhow, the outcome of practical planning or decision-making can seldom be divided into distinctive parts representing on the one hand internal goals, and on the other hand external goals, restrictions or pressure. The outcome should rather be seen as the result of a process of adjustment (Andersson and Ingelstam 1979), which however does not exclude situations involving direct negotiations between external and internal goals.

The motive of change – *why?* – will always be the greatest driving force when abandoning a secure situation. As established in chapter 3, the reasons for initiating a process of change vary depending on whose perspective is taken into consideration. As shown in table 1, the main driving force of system builders (or infrasystem organisations) generally is the survival (or expansion) of the system, while policy-makers, policy-implementers and planners generally have a broader array of goals, e.g. economic growth, equity, equality, and environmental as well as social sustainability. Referring to contemporary policy, sustainable development might be considered desirable – *what should be done* – while maintaining cheap and reliable infrasystem services rather is seen as a necessity – *what must be done*. However, increased problem awareness and a more progressive environmental policy supported by altered public opinions might reverse the state of things, regarding what must be done, and what should be done. If future generations consider effects such as climate change to be true threats against ecosystems and society, the view of what must be done might shift. In such a situation, cheap, reliable and easily accessible infrasystem services might be considered as desirabilities – but not at any price. Either way, it is easy to realise that the process of change gains from the utilisation of situations of opportunity, reducing the distance between what must be done, and what should be done – or even better, finding positive synergies between the necessities and the desirabilities.

Kaijser (1994) approaches the task of combining different interests in a slightly different manner. He advocates the search for the *lowest common denominator*, as a starting point when it comes to formulating visions. One example on the national level which might bring supporters of strong economic growth and environmentalists together, is the view that early investments, followed by new innovations, in energy efficient technology might result in profits and an advantageous position on the market of energy technology in the future when oil prices have increased even further and the political will to moderate climate change possibly has grown stronger on the international level.

A somewhat trivial conclusion, however important, is that the future challenge primarily lies in integrating objectives rather than highlighting potential conflicts of interest. This intricate but important process might take place within the framework of the 'early warning systems' (with the purpose of finding and utilising situations of opportunity) discussed in section 2.4 and in chapter 3. Purposefully designed 'early warning systems' in the form of network organisations might contribute with some new approaches of how to steer our society onto a more sustainable path. I think that those new approaches will be more innovative and potentially powerful, if the network organisations consist of actors with different agendas and organisational affiliations, compiled with *utility* and *function* in consideration, rather than setting out from *sectors* and *systems*.

Closing words

To sum up, the contributions to the research field associated with sustainable infrasystems in this thesis primarily has a conceptual character, helping to better understand the nature of the systems, and possibly facilitating the process of generating and evaluating future options. The contributions to the SITOP approach primarily concerns the applicability of the concept on infrasystems, and how various related socio-technical perspectives, such as the LTS approach, can fertilise the SITOP approach.

Some directions of where to look for situations of opportunity for infrasystem change, aiming for environmental sustainability, have been pointed out. Also some conditions affecting the extent of the field of options for different actors have been discussed. The perspectives used have indeed varied; from small opportunities to install environmental friendly infrasystem components in individual households, to socio-technical regime shifts at urban, or even national levels. We have seen that the top-down and network perspectives, involving for example system builders and operators, and public decision-makers and planners, implies intricate relations leading to conclusions in the borderland between politics and science. It might seem reasonable to promote the view that the changes needed call for totally new socio-technical regimes with a distinct orientation towards resource awareness and environmental consideration. A more moderate view is to promote the combination of changes perceived as necessary changes, with desired changes entailing environmental improvements. The so-called necessities might originate from bottlenecks and obstacles associated with the development of infrasystems, such as reverse salients and critical problems. Environmentally oriented public actors and policy-makers could either be content with the role of trying to identify and utilise spontaneously arisen situations of opportunity, or actively try to create reverse salients, critical problems, radical changes and regime shifts, by way of using available means of control. Either way, the choice is a question of political standpoints, rather than a conclusion of research.

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