



**CHALMERS**

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# **Literature Review of Practices in Sustainability Assessment of Transport Infrastructures**

- Identification of Issues and Knowledge Gaps

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## **Executive summary**

*Purpose* The purpose of this study was to identify the current best practices in sustainability assessment of transport infrastructures. This identification should further lead to the establishment of information regarding existing issues and knowledge gaps in the practice of sustainability assessment of transport infrastructures. The results from the study should also provide a foundation for a research project proposal. That is, a proposal for collaboration between Norwegian Public Roads Administration (NPRA) and Chalmers University of Technology in connection to sustainability assessment of transport infrastructures.

*Method* Information about practices in sustainability assessment of transport infrastructures together with information about attempts to improve these practices was gathered through a literature review. Further, the review also enabled identification of issues and knowledge gaps connected to sustainability assessment of transport infrastructures acknowledged in academic literature. The review targeted the terms “sustainability assessment”, “transport”, “infrastructure”, “road” and “strategic environmental assessment” and was limited to literature published around the years of 2000 to 2014.

*Results and discussion* There are many on-going practices in sustainability assessments of transport infrastructures around the world, although the practices vary in effectiveness. Environmental impact assessment (EIA), Strategic environmental assessment (SEA), Cost-benefit analysis (CBA), Multi-criteria analysis (MCA) and Life-cycle analysis (LCA) are all examples of methodologies that are used and CBA, MCA and LCA can also be incorporated in the procedures of EIA and SEA. In several countries there exist legal frameworks for sustainability assessment of transport infrastructures, like in the European countries through the EIA and SEA Directives. SEA acknowledges limitations of EIA and introduces wider perspectives to consider sustainability aspects more properly. However, sustainability assessment of transport infrastructures performed with SEA that considers sustainability aspects sufficiently and realizes strategic planning of these complex systems, seems to be at its infancy. Nevertheless, there do exist several studies connected to for example SEA that are reaching for improved sustainability assessments of transport infrastructures. Identified key issues and knowledge gaps are the requirement to include wider spatial and temporal scales, consider cumulative impacts and indirect effects and more effective incorporation of stakeholders. Other highlighted issues were the insufficient linkages between procedural stages in sustainability assessments, inadequate monitoring and that knowledge from other fields should be utilized further.

*Conclusions and perspectives* Issues and knowledge gaps that are identified as in need of being further assessed by research are provided in Table 1.

**Table 1: Overview of issues and knowledge gaps in connection to sustainability assessment of transport infrastructures.**

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<i>Wider perspectives</i>	<ul style="list-style-type: none"><li>• Inappropriate selection of spatial and temporal scales</li><li>• Need for a deeper understanding of long-term system effects and effects on the structure of society</li><li>• Wider spatial and temporal scales, consider cumulative impacts and indirect effects</li><li>• Planning carried out at a too low strategic level</li></ul>
<i>Stakeholder participation</i>	<ul style="list-style-type: none"><li>• Inadequate stakeholder participation initiated after decisions are already made</li></ul>
<i>Collaboration and communication</i>	<ul style="list-style-type: none"><li>• Between procedural stages, stakeholders, researchers and planners in different fields like land use, urban development and energy</li></ul>
<i>Combining knowledge</i>	<ul style="list-style-type: none"><li>• Utilizing knowledge that already exist and could be applicable from other fields</li></ul>
<i>Monitoring and follow-up</i>	<ul style="list-style-type: none"><li>• Insufficient monitoring of socio-economic but also environmental aspects</li></ul>

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These issues and knowledge gaps could provide a foundation for a research project in collaboration between Norwegian Public Roads Administration (NPRA) and Chalmers University of Technology in connection to sustainability assessment of transport infrastructures.

### **Keywords**

Strategic environmental assessment, Environmental impact assessment, road,

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# 1 Introduction

The size and complexity of megaprojects, like motorways, are constantly increasing according to Flyvbjerg (2014). Typically, these projects are very costly and imply the utilization of large amounts of resources, take many years to develop and construct, involve several stakeholders and the projects might affect millions of people.

At the same time as megaprojects in for example transport infrastructure become even larger and more complex, there is a requirement for more sustainable transport infrastructures that are considering environmental, economic and social issues. Transport infrastructure is one key point that is highlighted in the strategic research agenda developed by the European Road Transport Research Advisory Council (ERTRAC) (ERTRAC, 2010; ERTRAC, 2009). The aim of the strategic research agenda is to provide recommendations for priorities in research and innovation that in turn acknowledges the priorities for sustainable transport and environmental protection in Europe. The agenda was developed in order to contribute to significant improvements to the European road transport system. It addresses climate change and the environment as one of the challenges related to the road transport system that need to be considered in order to enable significant improvements. Infrastructure is one out of four research and innovation domains that are mentioned in the strategic research agenda (ERTRAC, 2010).

Another study that also acknowledges sustainability in connection to transport infrastructures, among other things, is the *white paper on transport* (EC, 2011a; EC, 2011b). The paper, which is developed by the European Commission (EC), states that the European transport system must change. It also provides a vision for a sustainable transport system and information about what needs to be done. According to EC (2011a), transport infrastructure investments have positive impacts on economic growth, accessibility and mobility but have to be planned in order to maximize economic growth and minimize negative environmental impact. Assessments of transport infrastructures are in general a trade-off between increased welfare connected to accessibility and mobility and negative consequences such as construction and operating costs and environmental impacts (Jonsson and Johansson, 2006). Economical, social and environmental aspects must all be considered in these assessments in order to ensure comprehensiveness. In turn, the multitude of trade-offs in these complex transport infrastructure systems needs procedures to be performed. The planning, and construction of transport infrastructures takes many years and they last for decades, which implies that the decisions that are made today will determine the transport in many years ahead (EC, 2011a; van Wee et al., 2005). However, although many transport infrastructure projects are constructed and there is a lot of published research in this topic, there is a disagreement on the actual benefits from transport infrastructure investments (Thomopoulos and Grant-Muller, 2013). In the study by Miceviciene (2012) different aspects of the validity of investments made to develop highway infrastructure are considered in the context of sustainability. The study concludes, based on analysis of the first European transport corridor; Via Baltica with focus on Lithuania, that the socio-economic effects following a development in highway infrastructure might be questioned. According to Flyvbjerg (2014), the benefits of megaprojects are usually overestimated and benefit shortfalls of such projects are common. According to (ECA, 2013), the forecasted returns by cost-benefit analysis (CBA) from investment, through EU cohesion policy funds, in road projects between 2000 and 2013 were not realized in several cases. The inspection of 24 EU cohesion policy funded road projects located in Germany, Greece, Poland and Spain could conclude that the total

cost of these projects had exceeded 3 billion euros. Flyvbjerg (2014) states that the management of megaprojects, as well as the selection of the appropriate project alternative, are crucial since there are so many resources involved in these projects. According to Flyvbjerg (2014), the consideration of economic, social and environmental impacts of megaprojects together with practices of informing policy, practice and public debate about these very costly projects has never been more important.

Sustainability assessment of transport infrastructures is very essential, specifically due to the aspects of high consumption of resources, land resource wasting and severe pollution (Zhang et al., 2013). At the same time, sustainability assessments of such infrastructure systems require an interdisciplinary approach that considers social, environmental and economic as well as engineering sciences (Alsulami and Mohamed, 2013). In order to manage the complexity of transport infrastructures and the trade-offs in these systems, there is a need for procedures to be performed. There is a need for sustainability assessment. In order to address the acknowledged requisite of improved consideration of environmental, economic and social aspects in connection to transport infrastructure projects there is a need to identify current best practices together with associated issues and knowledge gaps. Hopefully, this information can then be used to inform research on key issues and knowledge gaps in need of being addressed through research in order to obtain more sustainable transport infrastructures.

## **1.1 Purpose**

The purpose of this study is to provide information about what is currently performed in connection to sustainability assessment of transport infrastructures. Through this, existing issues and knowledge gaps in the practice of sustainability assessment of transport infrastructures should be identified. The study should also provide a foundation for a research project proposal in connection to sustainability assessment of transport infrastructures. More specifically, a foundation for a research project performed in collaboration between the Norwegian Public Roads Administration (NPRA) and Chalmers University of Technology should be offered.

This study intends to answer the following questions:

- What are the current best practices in sustainability assessment of transport infrastructures (Section 4)?
- Are there any lessons to be learned in connection to these best practices (Section 5)?

## 2 Method

Information about best practices in sustainability assessment of transport infrastructures was gathered through a review of international literature. The focus of the literature review was academic literature around the years of 2000 to 2014. The reason for this focus on fairly new academic literature is based on the purpose of the study to provide information about the current best practices of sustainability assessment of transport infrastructures. This study put a specific focus on SEA, despite it is stated the procedure is in its infancy, since this procedure addresses several limitations of other methods like EIA, CBA, LCA and MCA that are used within current practices (Section 4). This focus provides another reason why literature around the years of 2000 to 2014 were studied, since the SEA Directive first came into force in 2001 (EC, 2001). Examples of issues addressed by SEA, are the incorporation of wider perspectives and strategic thinking in sustainability assessment of transport infrastructures. SEA is also used widely within sustainability assessments of transport infrastructures (Section 4). Thus, the current practices connected to SEA were of specific interest to investigate.

The review is mainly based on selected literature from the databases Scopus and Web of Knowledge but also on selected literature from specific journals, namely *Environmental Impact Assessment Review* and *Impact Assessment and Project Appraisal*, as well as other sources. The search targeted the terms “sustainability assessment”, “transport”, “infrastructure”, “road” and “strategic environmental assessment” appearing in the title, abstract or keywords of the literature.



### **3 Background**

The legal provisions for sustainability assessment of transport infrastructure with a focus on SEA and EIA in EU are provided in this section. The EIA and SEA Directives are generally explained and the relationship between these two are described. Information about sustainability assessment performed on a more detailed level in connection to transport infrastructures is also given. It is found that these detailed level assessments, for example performed with LCA, are not considering wider sustainability aspects appropriately. However, the detailed assessments could be integrated in procedures like EIA and SEA as complements.

#### **3.1 Legal provisions for sustainability assessment of transport infrastructures**

Sustainability issues and challenges connected to transport infrastructure projects are acknowledged in EU for example through the EIA and SEA Directives. These directives provide procedures for sustainability assessment of certain transport infrastructure projects among others. EIA and SEA can be defined as procedural tools and they were developed in order to address decision-making processes (Podhora et al., 2013).

##### **3.1.1 EIA Directive**

The EIA Directive assesses environmental effects of projects that are likely to pose substantial effects on the environment (EU, 2012). The first version of the EIA Directive in EU came into force in 1985 (EC, 2014) and the first version has been corrected several times resulting in the current version of Directive 2014/52/EU (EU, 2014) that amends Directive 2011/92/EU (EU, 2012). The EIA Directive applies to a wide range of projects like infrastructure projects, energy industry, production and processing of metals and the extractive industry (EU, 2012).

##### **3.1.2 SEA Directive**

The aim of the SEA Directive is to provide for a high level of protection of the environment and to promote sustainability (Therivel, 2010; EC, 2001). Another objective of the SEA Directive is to integrate environmental considerations into the preparation and adoption of plans and programmes (EC, 2001). The SEA Directive, that is Directive 2001/42/EC (EC, 2001), is somewhat newer than the EIA Directive and has been in force since 2001. The SEA Directive applies to certain plans and programmes connected to for example transport, land use and energy (EC, 2001). Through the SEA protocol (UNECE, ?), the application of the SEA framework is also stressed in a trans-boundary context. There exist several guidelines and guidance documents for SEA (Partidario, 2012; SEPA, 2010 ; IAIA, 2002; UNECE, 2012; UNECE, 2011; EC, 2006; ODPM, 2005). Some of these guidelines have been developed for general use and others to guide SEA practices in specific countries. The European Commission (EC) also provides a guideline for SEA in transport planning specifically (BEACON, 2005). The U.S. Department of transportation, Federal Highway Administration, has a specific guidebook connected to transportation planning for sustainability (FHWA, 2011).

In comparison with EU, where the SEA Directive has been in force since 2001 (EC, 2001), the method of SEA is more recently implemented in the legal systems in other countries or there is perhaps no legal basis for the method. In China, SEA for expressway infrastructure planning was officially implemented in 2003-2004 (Zhou and Sheate, 2011). In other countries like Bolivia and Peru, legal provisions exist but more exactly how SEA should be approached is not clear (Kis Madrid et al., 2011). A study by McGimpsey and Morgan (2013)

evaluates potential benefits from application of SEA in regional transport planning in New Zealand where there is no legal requirement for SEA.

### **3.1.3 The relationship between the EIA and SEA Directives**

The EIA and SEA Directives complement each other to a large extent (EC, 2009a). While SEA identifies the best options in the early planning stage, EIA assess the effects of projects in the later stage (Arce and Gullón, 2000; EC, 2009a). According to Arce and Gullón (2000), SEA considers project alternatives, broadens the spatial and time perspectives and hence works in a more proactive manner rather than the reactive one of EIA. However, SEA was developed based on claims of EIA being unable to consider sustainability aspects (Thorne et al., 2014).

## **3.2 Sustainability assessment of transport infrastructure on a more detailed level**

There exists a lot of literature that deals with specific topics within the sustainability assessment of transport infrastructures. There are many examples of studies that focus on for example road pavement (Nicuță, 2013; Santero et al., 2011; Nicuță and Frunză, 2013; Dumitrescu et al., 2014; Gschösser and Wallbaum, 2013), noise from traffic (Oltean-Dumbrava et al., 2013; Oltean-Dumbrava et al., 2011; Collin, 2009), climate change and specifically CO<sub>2</sub> emissions (Fox et al., 2011) and landscape fragmentation (Girardet et al., 2013; Jaeger et al., 2008). There also exist a lot more studies that are focused on other specific topics, such as biodiversity and railway systems. The studies particularly investigate how sustainability issues can be handled within their specific topics connected to transport infrastructures. Many of the mentioned studies, especially those connected to road pavement, utilize tools like Life-Cycle Assessment (LCA). An example of another method that is used in the studies is MCA.

LCA and Life Cycle Costing (LCC) are methods that are applied on transport infrastructures like bridges (Zinke et al., 2012). However, according to Zinke et al. (2012) many inaccuracies and assessment difficulties exist. Especially in connection to social issues that can be quite difficult to assess quantitatively. Other requirements for improvement of LCA in connection to pavement emphasized by (Santero et al., 2011), are that the system boundaries for pavement LCAs must be expanded and the study scopes must be broadened. This is required to extensively and comprehensively quantify environmental impacts and to guide sustainability purposes in an effective way (Santero et al., 2011). According to Zinke et al. (2012), more holistic sustainability assessments on for example bridges are increasingly being demanded. Zinke et al. (2012), conclude that the external costs from a bridge can largely exceed the direct costs depending on the selection of boundary conditions, the traffic intensity and type of traffic route. Examples of external costs are costs from time-delays of infrastructure users and environmental costs from pollution while direct costs arise from the construction of the bridge. In the study by Zinke et al. (2012), a case study of a overpass bridge over a federal highway showed that the external costs of the bridge were approximately nine times higher than the direct costs during the construction. This emphasizes the great importance of considering social aspects and not only direct costs but also external costs. Manufacturing and maintenance costs should therefore be minimized together with external costs arising from social effects according to Zinke et al. (2012). The identified limitations of LCA to consider social aspects and the requirement of widened system boundaries and scopes of the tool identified in these detailed studies leads to considerations regarding the potential of LCA to properly address sustainability issues in connection to transport infrastructures.

Treville and Neri (2011) elaborate on the relationship between LCA and SEA and ask the question whether LCA should be used as an integrated part of procedures such as SEA and EIA. According to Treville (2011), there is a potential of LCA as an integrated part in for example transport infrastructure planning. Treville and Neri (2011) conclude that LCA could be used to evaluate alternative scenarios. However, LCA in itself hardly include any qualitative issues and this limitation of LCA makes it unable to properly consider all sustainability issues in connection to transport infrastructures. In connection to landscape fragmentation, Girardet et al. (2013) suggest the application of species distribution models (SDMs) in order to inform SEA and EIA in connection to the planning of major transport infrastructures that have impacts on for example biodiversity. The report by Strippel and Erlandsson (2004) covers methods and possibilities to apply LCA in SEA of transport infrastructures. According to Strippel and Erlandsson (2004), LCA is a cost-effective tool that can be used in complement with other tools, like EIA, that all have their place in the toolbox for SEA of transport infrastructures.

Social issues together with economic and environmental ones are all of interest to consider in sustainability assessments. In general, there is a demand for broader spatial and temporal scopes in environmental assessments of for example transport infrastructures (Arce and Gullón, 2000). According to Arce and Gullón (2000), a wider perspective is demanded when the purpose is to incorporate sustainability in large and complex projects, like transport infrastructure projects. This section point in the direction that the utilization of for example LCA of transport infrastructures on a more detailed level have limitations in considering wider sustainability aspects. Leading to the suggestion that methodologies like the SEA and EIA procedures are required in order to consider sustainability aspects including environmental, economical and social aspects. However, detailed sustainability assessments could have an important role in informing and being a complement to the EIA and SEA procedures. Following this background, the current best practice in sustainability assessment of transport infrastructures will be described in Chapter 4.



## 4 Best practices in sustainability assessment of transport infrastructures

The worldwide best practices in sustainability assessment in general are presented by Bond et al. (2013) through case studies on such assessments in the countries of England, Australia, Canada and South Africa. The procedures that are used by these countries in sustainability assessments are for example SEA, EIA and MCA. England, Australia, Canada and South Africa are all part of the state-of-art in sustainability assessment practice in general (Bond et al., 2013). This chapter identifies the best practices when sustainability assessment of transport infrastructure is considered specifically.

There exist many recent studies of sustainability assessment of transport infrastructure projects. The sustainability assessment methods that generally are used, in connection to these projects in the reviewed studies, are EIA and SEA. However, other methods like Cost-Benefit Analysis (CBA), Multi-Criteria Analysis (MCA) and Life-Cycle Analysis (LCA) are also applied and these methods can be incorporated into the SEA procedure for example. Further, other methodologies, European Research Area Network (ERA-NET) funded projects and sustainability rating systems that all are contributing to the practice in sustainability assessment of transport infrastructures will be described. Finally, governance and policy in connection to sustainability assessment of transport infrastructures are touched upon. This chapter intends to answer the question of what the current best practices are in sustainability assessment of transport infrastructures. Figure 1 provides an overview of the practices in sustainability assessment of transport infrastructures that will be described in this chapter. There are additional practices that also are described in this section. These are connected to other methodologies from recently published articles, European Research Area Network (ERA-NET) funded projects, sustainability rating systems, governance and policy.

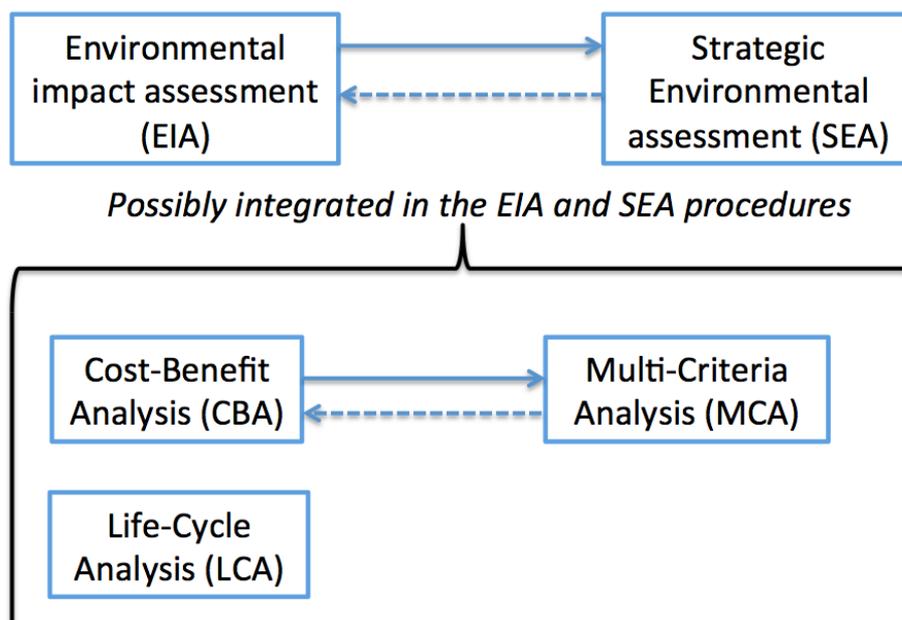


Figure 1: Overview of the practices in sustainability assessment of transport infrastructures. Additional practices that are described in this chapter are connected to other methodologies, European Research Area Network (ERA-NET) funded projects, sustainability rating systems, governance and policy.

#### **4.1 Environmental Impact Assessment (EIA)**

The integration of environmental issues and mitigation of impacts, in connection to the planning, design, construction and maintenance of road infrastructure, is mainly done by using EIA (Arts and Faith-Ell, 2012). EIA is recognized internationally, being used in more than 120 countries, and is also often required for environmental management of transport infrastructure projects (Thorne et al., 2014; Arts and Faith-Ell, 2012).

In the studies by Loro et al. (2014) and Bassi et al. (2012) the sustainability assessment of transport infrastructure projects have been conducted by applying EIA. The reviewed transport infrastructure projects in these studies are road- and highway-corridor planning and the projects are located in Spain, United Kingdom (UK) and Italy. The analysed EIA studies in the study by Bassi et al. (2012) experienced the ability of EIA to enhance integration of sustainability values. Benefits like reduced planning risk and operational costs and improved reputation and credibility were also identified.

#### **4.2 Strategic Environmental Assessment (SEA)**

The development of SEA has its origins in claims of the inability of EIA as a process to consider sustainability issues, namely environmental, economic and social issues (Thorne et al., 2014; Arts and Faith-Ell, 2012; Fundingsland Tetlow and Hanusch, 2012). The development of SEA is also based on the statement that sustainability issues should be addressed earlier in the planning process (Thorne et al., 2014). The introduction of SEA, through the SEA Directive, was highly significant in improving the inclusion of wider impacts from transport infrastructure plans (Thomopoulos and Grant-Muller, 2013). According to Fischer (2001), SEA strengthens project EIA and provides a wider consideration of impacts and alternatives. Other shortcomings of project level EIA that the SEA procedure pursue to address, are the limited effect on decision-making, the compact timescale and inappropriate consideration of cumulative effects and insignificant monitoring (Zhou and Sheate, 2011). According to Thorne et al. (2014), the procedure of SEA has been widely applied.

SEA incorporates strategic thinking into decision-making. Strategic thinking includes having a long-term vision and objective, flexibility to handle complex systems, adaptability to varying contexts as well as having the focus of considering wider aspects connected to time, space and points of view (Partidario, 2012). According to Partidario (2012), the flexible attribute of strategic thinking implies an understanding of the system links and lock-ins as well as accepting uncertainty. More specifically, SEA for example incorporates a strategic thinking through strong interaction among stakeholders and frequent iteration in the decision-making process. The integration of social, environmental and economical aspects is also part of the strategic acting of SEA (Partidario, 2012).

There are many examples of articles that consider SEAs of transport infrastructures. In the studies by Kontić and Dermol (2015), McGimpsey and Morgan (2013), Kis Madrid et al. (2011) and Zhou and Sheate (2011) the sustainability assessment of transport infrastructure projects have been conducted by applying SEA. Examples of the transport infrastructure projects in these studies are road- and highway-corridor planning and the projects are located in Slovenia, New Zealand, Bolivia, Colombia, Peru and China. The study by McGimpsey and Morgan (2013) of SEA in a non-mandatory context concludes that, compared to the existing process in New Zealand, the incorporation of SEA would most importantly lead to the usage of baseline information and to the development and environmental assessment of alternatives. Kontić and Dermol (2015) identified SEA benefits like improved plans and reduced

pollution, wider participation of stakeholders and transparent and justified decision-making. Karlsson et al. (2014) review 23 environmental reports and environmental impact statements from SEAs and EIAs of road and railway projects in Sweden and UK between 2005 and 2013. Lobos and Partidario (2014) analyse 100 SEA cases from around the world mainly through examining environmental reports from cases conducted in the years of 2007 to 2012. The majority of the cases analysed by Lobos and Partidario (2014) was connected to the sectors of energy, spatial planning and transport. Therivel et al. (2009) consider English experiences in SEA of local-level spatial plans of for example transport and Fischer (2006) utilizes a generic SEA framework to evaluate Trans-European Transport Networks (TEN-Ts) in Germany and England.

Benefits identified in literature of SEAs in connection to transport infrastructure projects are similar to the general benefits of SEA that are pointed out by Therivel (2010). These general benefits are for example that SEA starts earlier than other methodologies, like project EIA, and incorporates strategic thinking that can influence what type of projects that are chosen. SEA also address cumulative impacts that are hard to assess on the project-by-project level, informs decision-makers and leads to a more transparent decision-making processes (Therivel, 2010).

Techniques that can be used within SEA to predict and evaluate impacts of different alternatives are for example CBA, MCA and LCA (Therivel, 2010). These evaluation and prediction techniques will be described further in the following sections of this chapter. In the study by Fischer (2006), MCA and CBA are incorporated in a generic SEA framework for transport planning in the tier of decision-making where different programmes are considered. Other evaluation and prediction techniques that can be used within SEA are scenario analysis and spatial analysis tools (Therivel, 2010). Examples of studies that focus on the integration of scenario analysis and spatial analysis tools within SEA for transport infrastructures are the ones by Zhu et al. (2011) and Ramachandran and Linde (2011) respectively. According to Jonsson and Johansson (2006), SEA together with CBA, MCA and EIA might encourage more balanced infrastructure assessments where trade-offs in economic terms but also other perspectives are considered more widely and in longer terms.

### **4.3 Cost-Benefit Analysis (CBA)**

Currently, CBA is the most widely used approach for the assessment of transport in Europe and both funding instruments and practice promote the utilization of this tool (Thomopoulos and Grant-Muller, 2013). The studies by Kontić and Dermol (2015), Finnveden and Åkerman (2014) and Schade et al. (2000) provides examples of when CBA have been considered in connection to sustainability assessment of transport infrastructures in Slovenia, Sweden and Germany respectively. In the study by Kontić and Dermol (2015), it is argued that CBA should be used in the effectiveness evaluation of SEAs.

Although its wide application, many limitations have been identified of CBA in considering social, environmental and strategic issues (Thomopoulos and Grant-Muller, 2013). These limitations are associated with the fact that all impacts should be monetized in CBA. However, this is not possible in many cases and sometimes this is due to the lack of resources (Thomopoulos and Grant-Muller, 2013). There are increasing claims saying that other approaches than the conventional assessment methodologies, of for example CBA, are needed in order to evaluate sustainability of transport infrastructures (López and Monzón, 2010). van Wee (2012), reflects on MCA as an alternative and complement to CBA in order to address the difficulty of CBA to include impacts that are not easily monetized. Examples of

such impacts are nature effects, specific social effects and distribution effects. According to Thomopoulos and Grant-Muller (2013), better combination of quantitative and qualitative methods, demanded by both theorists and practitioners, and a recognition of the limitations of CBA is preferably reached by combining CBA with other methods, like MCA.

#### **4.4 Multi-Criteria Analysis (MCA)**

MCA are like CBA dominant in the practice of transport assessment in Europe and these tools are often used in complement to each other (Jonsson and Johansson, 2006). Where CBA possibly fails in the monetization of certain impacts, MCA is preferable since this tool does not strive to monetise impacts (Thomopoulos and Grant-Muller, 2013). This implies that more impacts can be included. In MCA, certain impacts or measures identified as relevant for the specific project together with assigned weights of these measures are used to compare different alternatives (Therivel, 2010). MCA integrates information about impacts with the views and opinions of stakeholders and decision-makers (Geneletti, 2005). Concerns and criticism have been raised in connection to the introduction of subjectivity that the assignment of weights to impacts in MCA implies (Thomopoulos and Grant-Muller, 2013; van Wee, 2012). The assignment of weights to impacts is also potentially complex and time-consuming (Thomopoulos and Grant-Muller, 2013). However, according to Thomopoulos and Grant-Muller (2013) MCA improves transparency since the preferences of the decision-makers must be expressed.

Examples of studies of MCA in connection to transport infrastructures are the ones by López and Monzón (2010), Geneletti (2005) and Abbas (2003). The study by López and Monzón (2010) propose a multi-criteria model for the assessment of transport infrastructure plans. A case study is also given based on a rail project included in the Spanish Transport and Infrastructure plan for 2005-2020 (López and Monzón, 2010). Geneletti (2005) utilizes MCA in order to evaluate the impacts of different road corridor alternatives in Italy. According to Geneletti (2005), comparing project alternatives implies balancing of different impacts and this type of assessment can preferably be performed through MCA. Alternative road arrangements for a freeway in Egypt were compared with a multi-criteria scoping framework including EIA in a study by Abbas (2003). Several criteria, like environmental, economic and social aspects, were included in the assessment and Abbas (2003) could conclude that the framework were successful both in considering different road alternatives and in selecting the most preferable alternative from an environmental point of view.

#### **4.5 Life-Cycle Analysis (LCA)**

Several examples of the utilization of LCA in connection to sustainability assessment of transport infrastructures have already been provided in Section 3.2. In these examples, LCA are used in the assessment of for example road pavement. However, the question was raised whether the utilization of LCA in these studies do incorporate sustainability issues and wider perspectives to a satisfactory extent.

#### **4.6 Other methodologies**

Further, there exist other methodologies that have been developed to improve sustainability assessments of transport infrastructure projects. Examples of these methodologies are the Regional Advanced Mitigation Planning (RAMP) framework, the Top-Down-Bottom-Up (TDBU) methodology, the SUSTainable Mobility INequality Indicator (SUMINI) approach and the hybrid fuzzy sustainability assessment model. It can be mentioned that some of these methodologies can also be applied on other civil engineering and infrastructure project types than transport infrastructures.

### *The Regional Advanced Mitigation Planning (RAMP) framework*

In the study by Thorne et al. (2014), environmental impacts from several planned transportation projects, of which a majority is road projects, in the San Francisco Bay Area in the US, are assessed. The project-by-project analysis of the transportation projects indicated only minor environmental impacts. However, it could be seen that for example several of the studied species were impacted by more than one of the transport projects. The large extent of spatial cumulative effects provided arguments for the incorporation of the RAMP framework that acknowledges these cumulative impacts. RAMP can be seen, besides being a framework, as a set of guiding policies and a method that integrates impacts from transportation infrastructures with sustainability. The framework is emerging in the practice of transportation authorities in the U.S.

According to Thorne et al. (2014), the RAMP framework addresses many recognized inefficiencies in the implementation of transportation infrastructure projects in the US. These inefficiencies are connected to both increased costs and the loss of potential land acquisition opportunities due to project-by-project environmental mitigation. These inefficiencies are addressed in the RAMP framework since RAMP provides a wider spatial perspective through emphasizing a regional approach, where aggregated impacts are assessed early. Rather than through a project-by-project assessment approach that usually is performed at the end phase of a project. The engagement of many stakeholders that is realized through the RAMP framework also allow an early incorporation of environmental issues in the development of transport infrastructures (Thorne et al., 2014). The RAMP framework acknowledges the need for a better linkage between EIA and SEA (Thorne et al., 2014) and addresses the limitation of SEA processes that in many cases do not progress from the planning stage to the implementation stage.

### *The Top-Down-Bottom-Up (TDBU) methodology*

The study by Oltean-Dumbrava et al. (2014) introduces the TDBU methodology, which was developed in order to define bespoke sustainability criteria for unique civil engineering and infrastructure projects like for example roads, tunnels and bridges (Oltean-Dumbrava et al., 2014). The methodology combines main research methods to define sustainability criteria for the assessment of these specific projects.

According to Oltean-Dumbrava et al. (2014), existing sustainability assessment tools, like the civil engineering environmental quality assessment and audit scheme (CEEQUAL) (Section 0), are able to highlight sustainability issues that should be considered and assessed. However, many of these tools are unable to identify the most significant sustainability criteria for unique civil engineering and infrastructure projects. Identifying a generic set of sustainability criteria that can be applied on all unique projects are impossible according to Oltean-Dumbrava et al. (2014). Due to this, the main aim of the article is to define an approach that can be used to define bespoke sets of sustainability criteria, considering social, environmental, economic and technical aspects, for distinctive projects.

There are two general approaches for developing sustainability frameworks for infrastructure projects (Oltean-Dumbrava et al., 2014). These approaches are the top-down approach and the bottom-up approach. In the top-down approach, the sustainability framework together with sustainability criteria are defined by experts while in the bottom-up approach the definitions are made by various stakeholders. Considering the approaches separately, the top-down approach could imply a perspective that is too narrow resulting in that important criteria only identifiable through consultation with relevant stakeholders are overlooked.

While the bottom-up approach could imply a process that takes a lot of time and leads to a model that is too complex. Oltean-Dumbrava et al. (2014) argue that the preferable solution would be to combine these approaches. In the TDBU methodology, experts provide a definition for sustainability, a framework and also provide suggestions for sustainability criteria and indicators while the role of the stakeholders is to comment and validate the suggested sustainability criteria. According to Oltean-Dumbrava et al. (2014), MCA together with the rating approach are the main sustainability assessment approaches in literature, which are used in sustainability assessments of civil engineering projects.

The TDBU methodology is applied on noise reducing devices (NRDs), which are a large part of the transport infrastructure in Europe, in order to provide an example of the methodology. Oltean-Dumbrava et al. (2014) conclude that several sustainability criteria were identified for NRDs that probably would not have been able to assess within the general sustainability assessment tools. They also conclude that the TDBU methodology could be used to improve the sustainability criteria that are used in for example CEEQUAL.

#### *The Sustainable Mobility Inequality Indicator (SUMINI) approach*

Thomopoulos and Grant-Muller (2013) review the dominant methodologies and the current practice in the assessment of transport infrastructure projects and identify a gap in the assessment of these projects. The gap is connected to the wider impacts that might have been omitted in the CBA of transport infrastructure projects. Examples of wider impacts that are mentioned in the study by Thomopoulos and Grant-Muller (2013) are socio-economic impacts, externalities, environmental impacts, land use planning, habitat fragmentation, equity and health impacts. According to Thomopoulos and Grant-Muller (2013), communication between disciplines is one thing that is required in order to significantly improve assessment frameworks of transport infrastructures.

Thomopoulos and Grant-Muller (2013) propose the SUMINI approach as a method for incorporating these wider impacts. The SUMINI approach incorporates wider impacts, with a focus on equity that is a key feature of sustainability, in the assessment of transport infrastructures and the approach is based on MCA and a composite indicator. The development of the SUMINI approach is based on the broad acknowledgement on the limitations of CBA, a methodology that has a dominant position in the assessment of transport projects in Europe, to consider wider impacts of such projects. According to Thomopoulos and Grant-Muller (2013) there have been continuous efforts to acknowledge the limitations of CBA through complementing this method with MCA.

Two Trans-European Transport Networks (TEN-Ts) are studied by Thomopoulos and Grant-Muller (2013) in order to evaluate the applicability of the SUMINI approach and to identify benefits of including wider impacts in the assessments of transport projects. It has been pointed out that the benefit-to-cost ratio does not exclusively justify TEN-Ts and that it would be of interest to investigate further benefits that might have been omitted by CBA. Examples of benefits with the SUMINI approach are that theory and practice are connected which lead to a more transparent decision-making. Theory and practice are linked in the SUMINI approach through pairwise comparisons of equity types and principles. This method provides stakeholders with information about the context and with a structure. Other benefits with the SUMINI method are that alternative opinions might be applied, opinions on equity become endogenous rather than stated externally that is common in practice. Further, ex-post analysis of TEN-Ts might lead to mitigation and compensation measures in the future. The SUMINI method addresses a current deficiency in the assessment of for example large bridge

projects in UK and China. This deficiency is the lack of provision of a quantified output that can inform decision-making and strategic planning. The SUMINI method can provide this quantified output through the utilization of a composite indicator that includes a variety of viewpoints of stakeholders.

#### *Hybrid fuzzy sustainability assessment model*

Alsulami and Mohamed (2013) present the hybrid fuzzy sustainability assessment model and provide an example of its application on a regional rail transport infrastructure project in Australia. The Hybrid fuzzy sustainability assessment model quantifies sustainability performance while considering interactions among indicators. The model is based on fuzzy set theory, which is used to consider uncertainties in the sustainability assessment process, and on fuzzy cognitive maps, a modelling methodology for complex systems. According to Alsulami and Mohamed (2013), the interaction between sustainability components, that is one of the most critical sustainability principles, is usually ignored in quantification models of sustainability performance for infrastructure projects. Excluding the interactions among sustainability indicators might lead to uncertain descriptions of the sustainability of transport infrastructure systems. Another limitation of these models is that uncertainty is not appropriately assessed. The hybrid fuzzy sustainability assessment model, on the other hand takes the interaction among sustainability components into consideration while quantifying sustainability performance. The example of the hybrid fuzzy sustainability assessment model applied in a regional rail transport infrastructure project revealed that the management of the complexity of sustainability assessment by decision-makers could be improved if the model is used. Improved capability of decision-makers to handle complexity was achieved through the consideration of interactions between sustainability indicators in the model.

#### **4.7 European Research Area Network (ERA-NET)**

Coordination and implementation of road research in Europe is achieved through the ERA-NET Road programme that was funded by the European Commission and the 7<sup>th</sup> Framework Programme. ERA-NET Road is a trans-national joint research programme that in 2011 funded research within the three subjects of Mobility, Design and Energy (Carlson and Folkesson, 2014). This section will focus on the ERA-NET Road Energy programme entitled “Sustainability and energy efficient management of roads”. The programme was initiated and funded in co-operation of the National Road Authorities (NRAs) in Germany, Denmark, Ireland, Netherlands, Norway, Sweden and UK (Carlson and Folkesson, 2014). Four different projects are included in the programme:

1. Sustainability for National Road Administrations (SUNRA)
2. CO<sub>2</sub> Emission Reduction in road Lifecycles (CEREAL)
3. Life Cycle Considerations in EIA of Road Infrastructure (LICCER)
4. Modelling Infrastructure influence on Road Vehicle Energy Consumption (MIRAVEC).

These projects were carried out between 2011 and 2014, addressing the overall aim of the ERA-NET Road Energy programme to improve the understanding and performance of sustainability development. The objective was also to consider the whole life cycle of sustainability and energy efficiency and to develop tools for decision-making that have practical applications to all stages of road planning, design, construction and maintenance (Carlson and Folkesson, 2014). The four projects identify some existing tools that are used within the scope of each project.

### *Sustainability for National Road Administrations (SUNRA)*

The primary objectives of the SUNRA project are to define sustainability within the context of national road administrations (NRAs) in Europe and identify how sustainable development should be measured and integrated at a strategic level in decision-making (Harmer and Sowerby, 2014). A further objective was to develop a sustainability rating system framework for use within NRAs to improve performance of road construction and road management. The objectives were addressed by assessing the practice of NRAs in sustainability for example through a literature review. It could be concluded that NRAs take quite different routes towards sustainability. The literature review and investigation of current practice of NRAs lead to the development of the SUNRA project framework. The framework is a planning tool based on Microsoft Excel that provides an opportunity for NRAs to identify appropriate sustainability topics and indicators in for example transport infrastructure projects. The planning tool was developed for the identification, assessment and follow-up of sustainability in connection to NRAs and road projects (Carlson and Folkeson, 2014). Harmer and Sowerby (2014) state that the tool should be implemented early in the planning phase of a project so that all significant issues are considered appropriately.

### *CO<sub>2</sub> Emission Reduction in Road Lifecycles (CEREAL)*

The CEREAL project develops a tool for calculating CO<sub>2</sub> emissions from road pavement construction and maintenance based on existing tools and requirements for a new tool (Carlson and Folkeson, 2014). Existing tools for estimating CO<sub>2</sub> emissions of road pavement construction and maintenance were identified as well as several limitations of these tools. One identified limitation was for example that the existing tools tend to focus on the construction of new roads although about 90 % of the road construction works in Europe are dedicated to maintenance and upgrading of already existing roads. Other limitations were the requirements of large amounts of data and the lack of transparency of the models that generally had complex structures. The developed CEREAL model, called the CEREAL Carbon Road Map, should serve as a decision tool for NRAs and be harmonized on an EU level (Trafikverket, 2014; Carlson and Folkeson, 2014).

### *Life Cycle Considerations in EIA of Road Infrastructure (LICCER)*

In the LICCER project a LCA model is developed, based on existing methodologies and tools, to be used in the early stages of transport planning (Potting and Brattebø, 2014). The model was developed to be used in the comparison of road corridor alternatives and can be integrated in EIA, the socio-economic assessment for example through CBA and in the overall environmental assessment (Carlson and Folkeson, 2014). The LICCER model considers energy use and emissions of CO<sub>2</sub> related to both the construction of infrastructures and to the traffic that is using the road. This is done in order to evaluate road corridor alternatives and identify the most suitable alternative. The LICCER model uses default values on many parameters, however these can and should be substituted with project-specific values when possible (Carlson and Folkeson, 2014). Two case studies, one in Sweden and the other in Norway, could conclude that traffic dominates over infrastructure construction when it comes to energy use and CO<sub>2</sub> emissions. However, the importance of energy use and CO<sub>2</sub> emissions from infrastructure construction increase when the difference in road-distance of alternatives becomes smaller. The importance of infrastructure construction will also increase through the improvement of traffic in efficiency and reduction of carbon emissions from traffic that is promoted by European policies (Carlson and Folkeson, 2014).

### *Modelling Infrastructure influence on Road Vehicle Energy Consumption (MIRAVEC)*

According to (Carlson and Folkeson, 2014), the CO<sub>2</sub> emissions from road transport constitute a significant part of the total greenhouse gas (GHG) emissions in the society. However, there is a possibility to reduce these emissions by improving road infrastructures and characteristics that have implications on fuel consumption (Haider and Benbow, 2014; Carlson and Folkeson, 2014). The MIRAVEC project was initiated with the aim of providing recommendations for road infrastructure design and operation. The recommendations should further lead to reduced energy consumption and associated CO<sub>2</sub> emissions from road transport (Carlson and Folkeson, 2014). Many road infrastructure variables associated to important effects that contribute to the energy used by road vehicles were identified in the MIRAVEC project and divided into group (Carlson and Folkeson, 2014). The considered road infrastructure variables contribute to the energy used by road vehicles from the interaction between road vehicles and road infrastructures specifically. There were two groups of effects that were identified as most likely to be controllable by NRAs. These are effects of pavement surface characteristics and effects of road design and layout. The effects are controllable by NRAs through road planning and construction or monitoring and maintenance (Carlson and Folkeson, 2014). The MIRAVEC tool, which is based on an Excel spreadsheet, combines several models for fuel consumption. The input data to the MIRAVEC tool are both global data, for example the distribution of traffic vehicles and traffic flow distribution, and local data, like the layout of the road and the traffic volume. The MIRAVEC tool should be used in the road planning phase in order to evaluate alternatives for construction and maintenance of roads.

#### **4.8 Sustainability rating systems**

Other practices in sustainability assessment of transport infrastructures are for example the application of assessment and reward schemes and rating schemes. There exist many sustainability rating systems that are applied on transport infrastructures around the world. Examples of sustainability rating systems that are denoted as fully developed and in use by Sowerby (2012) are CEEQUAL in UK, Greenroads<sup>TM</sup>, FHWA INVEST, GreenLITES and I-LAST<sup>TM</sup> in U.S. and GreenPave in Canada. The latest versions of these sustainability rating systems were launched between 2009 and 2012. Further, there exist many sustainability rating systems that are being developed in UK, Ireland, U.S., Netherlands, Australia and Canada. The study by Sowerby (2012), which provides an overview of the best practices in sustainability rating systems around the world, was performed to provide information for a ERA-NET Road project named SUNRA, see Section 4.7.

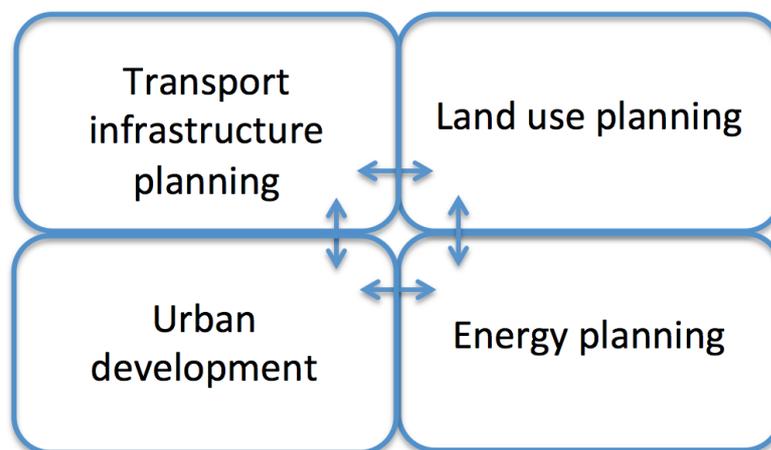
The systems that are described in the study by Sowerby (2012), are more than simply checklists or design standards and they primarily apply to transportation and roadways or to civil infrastructures where transportation is one part. Some differences between these systems are how many stages in the transportation life-cycle that they apply to and if quantitative or qualitative methods are used (Sowerby, 2012). Other differences can be found in the way that the rating is performed, how credits are weighted and if the systems require third-party certification or not. All the mentioned sustainability rating systems focus on transportation except CEEQUAL that concentrates on infrastructures. Therefore, CEEQUAL will be described somewhat further in Section 0.

## *Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL)*

In 2003 when the development of CEEQUAL was initiated, it was the first rating system for civil engineering projects. The development of CEEQUAL from 2003 to 2012, when the latest CEEQUAL Version 5 was released, has widened the perspective of the scheme from concentrating on environmental aspects to fully incorporate sustainability issues (Sowerby, 2012). Up to date, CEEQUAL is the leading methodology for the assessment of civil engineering and public realm projects, like transport infrastructure projects, in the UK (Ghumra et al., 2011). The scheme can be applied to transport infrastructure projects like bridges, highways and roads. CEEQUAL is an assessment and a reward scheme that evaluates sustainability of this type of projects and many case studies of CEEQUAL assessments can be found on the CEEQUAL webpage (CEEQUAL, 2014). Ghumra et al. (2011) analyse 24 CEEQUAL projects with the aim of understanding the relationship between overall scores and scores connected to the specific sections of transport and energy. The majority of the analysed CEEQUAL projects are road projects, namely 17 projects, the other four plus three projects are bridge and rail projects respectively. The study reveals that a number of core transport topics, like energy, have a small influence on the overall CEEQUAL score. Because of this, some recommendations for improving CEEQUAL are identified (Ghumra et al., 2011).

### **4.9 The relationship of transport with land-use, urban development and energy**

Several authors acknowledge the need for combining transport infrastructure planning with for example land use planning, urban development and energy planning (Thomopoulos and Grant-Muller, 2013; Jonsson and Johansson, 2006; Yigitcanlar and Dur, 2010; Mörtberg et al., 2013; Mörtberg et al., 2012; McCalley et al., 2010; Ibanez et al., 2008). These fields are tightly connected (Figure 2), for example new transport infrastructures have implications connected to both land use and the requirements for energy.



**Figure 2: Transport infrastructure planning is tightly connected to other fields such as land use planning, urban development and energy planning. These other fields are also connected in various ways, and the planning procedures in these four fields could preferably be combined.**

Transport infrastructure, accessibility and land use are interrelated and in the ideal case these should be assessed in the same framework (Thomopoulos and Grant-Muller, 2013). According to Thorne et al. (2014), there is a link between expanding transport infrastructures and the functionality of growing urban areas. However, the regional and spatially cumulative environmental impacts from transportation projects in the expanding urban areas all over the world are usually not assessed (Thorne et al., 2014). Jonsson and Johansson (2006) state that

land use and traffic planning must be coordinated in order to for example follow policies with the aim of limiting travels by car in cities. According to Mörtberg et al. (2013), to initiate competence building for sustainability assessment of urban systems it is crucial that the interaction between several fields like urban form, land use and transport are acknowledged. In the study by Yigitcanlar and Dur (2010), the Sustainable Infrastructure, Land use, Environment and Transport model (SILENT) is introduced. The aim of the model is to assist planners and decision-makers in sustainable urban development. Environmental, economic and societal aspects are integrated in order to acknowledge the linkage between these aspects and the dynamics of a system. The SILENT model considers for example both land use and transport infrastructure. According to Mörtberg et al. (2012), the growth of urban areas need to be both energy and transport efficient in order to achieve sustainable urban development.

McCalley et al. (2010) and Ibanez et al. (2008) acknowledge the connection between transport and energy planning. According to Ibanez et al. (2008), freight and passenger transportation systems with adherent transport infrastructures are one of the most significant contributors to energy consumption and greenhouse gases in any nation. McCalley et al. (2010) and Ibanez et al. (2008) develop model capability for long-term national planning that acknowledges interdependencies of electric and transport infrastructures. These interdependencies are stated to be of specific interest based on the introduction of electrified transportation.

#### **4.10 Governance and policy**

This section considers governance and policy in connection to sustainability assessment of transport infrastructures. Governance approaches, uncertainties and resilience together with policy assessment are all topics that are described briefly in this section.

##### **4.10.1 Governance approaches**

Several articles address governance in connection to sustainability assessments of transport infrastructures (Sheate, 2012; Zanon, 2011; Steele and Dodson, 2014; Therivel, 2013; Scanlon and Davis, 2011). In order to address the recognized deficiency in accounting of unsustainable organisational and social performances, Fraser (2012) reflect on assemblages of change that supports, or restrains, sustainability thinking at an organisational level. The reflection is based on interviews regarding the application of a new social accounting technology, sustainability assessment model (SAM), on for example a large transport infrastructure project in New Zealand. According to (Zinke et al., 2012), research connected to social aspects is still in its infancy, especially when infrastructures and bridges are considered.

There exist many governance approaches to overcome the problem of unsustainable transport infrastructures. Arts and Faith-Ell (2012) emphasize that approaches should be integrated in order to enable transfer of information, communication, learning from experience as well as an environmental management that is adaptive. According to Arts and Faith-Ell (2012), many decisions connected to the sustainability performance of transport infrastructures are not made until after the planning phase. As well, many stakeholders in combination with inadequate follow-up imply that information is not transferred from the planning phase to the construction and implementation phase. However, there are new approaches emerging in the recent practice of transport infrastructure developments (Arts and Faith-Ell, 2012). According to Arts and Faith-Ell (2012) there are various approaches to handle these issues, like increased collaboration between governmental, public and private stakeholders. Other trends in these emerging practices are a better linking of stages in the planning process, market parties like contractors and banks that are usually only involved in the implementation stages

are involved earlier and a self-responsibility of private companies are some of these trends. Others are the emergence of broader scopes of the practices that are relating to economic, environmental and social issues and that third parties, like the civil society, are involved. These trends that arise partly due to the increased emphasize put on sustainability, also implicates that new approaches for governance appear. Instruments like innovative contracting, green procurement and environmental labelling systems are all examples of governance approaches that could be especially relevant for the formation of sustainable transport infrastructure projects (Arts and Faith-Ell, 2012). Green procurement and innovative contracting are environmental policy instruments used by authorities and companies to enhance the environmental performance of projects (Arts and Faith-Ell, 2012). Green procurement implies that environmental considerations are integrated in purchasing policies, programmes and actions. Innovative contracts are more integrated in all the stages of the process, not only in the implementation stage but also in the planning stages.

#### **4.10.2 Policy assessment**

Wilson and McDaniels (2007) and Basbas et al. (2009) considers aspects connected to structured decision-making for complex systems such as transport infrastructures and policy assessment of transport infrastructure systems respectively. Wilson and McDaniels (2007) state that decision support tools, like influence diagrams, can provides structures for complex decision problems. Podhora et al. (2013), analyse projects, funded by the European Framework Programmes 6 and 7 in the years of 2002 to 2011, which develops tools for ex-ante policy impact assessment (IA) for example for transport policy areas. IA was established by EC in order to promote improved quality and transparency of regulations (Podhora et al., 2013). The transport policy areas addressed by the projects included general but also specific aspects on transport like freight and infrastructure. The scope of policy areas treated by the developed tools in the European Framework Programmes 6 and 7 were rather narrow, however other policy areas than transport that were addressed by the tools are the environmental and agricultural policy areas (Podhora et al., 2013). (Podhora et al., 2013) conclude that the developed tools primarily were quantitative, only a few tools were qualitative and participatory. The focus was seldom on all three dimensions of sustainability, environmental aspects were primarily addressed and social aspects were usually not considered, and the inclusion of only a limited amount of impact areas in the tools also led to an unbalanced coverage of sustainability issues. Specifically, the tools for transport policy areas commonly focused on only one impact area. The tools were neither designed for several jurisdictional levels but usually for the European jurisdictional level, therefore not promoting the analysis of interactions between policy levels. Multi-level governance approaches addressed in the developed tools were missing (Podhora et al., 2013).

#### **4.10.3 Uncertainties**

There is a need to acknowledge uncertainties and pluralities of perspectives that are inherent of complex systems like transport infrastructures (Funtowitz et al., 1999). According to Funtowitz et al. (1999), post-normal science is the most general methodology for managing complex issues. Lobos and Partidario (2014) analyse 100 SEA cases from around the world mainly through examining environmental reports. The majority of the cases analysed was connected to the sectors of energy, spatial planning and transport. According to Lobos and Partidario (2014), it is essential that uncertainties and dynamics of complex systems are addressed in assessments and predictions. However, none of the analysed cases addressed uncertainty analytically and only a few cases recognized issues related to uncertainties.

## **5 Lessons to be learned?**

The reviewed articles in Chapter 4 identify the best practices in sustainability assessment of transport infrastructure projects. EIA are widely used, however another procedure for sustainability assessment of for example transport infrastructures, namely SEA, was developed from this procedure, addressing limitations of EIA. Other methodologies that are being used in connection to sustainability assessment of transport infrastructures are for example CBA, MCA and LCA. These are used individually or they can be integrated within EIA and SEA. CBA are used widely, however MCA was developed to address limitations of CBA. Further, the relationship of transport with land use planning, urban development and energy planning are acknowledged in literature and it is argued that these planning processes preferably should be combined. Based on the identified current best practices in sustainability assessment of transport infrastructures, this chapter addresses the question whether there are some lessons to be learned in connection to these practices. First, sustainability assessments performed on transport infrastructures already in place are described. Then studies that evaluate the performance of sustainability assessments of transport infrastructures are presented and issues together with knowledge gaps are identified. Information about the effectiveness of specific topics in EIA and SEA, the overall effectiveness of EIA and SEA and the effectiveness of the SEA Directive are finally provided. The identification of several issues and knowledge gaps, summarized in Chapter 6, connected to sustainability assessment of transport infrastructures do lead to the insight that there are several lessons to be learned.

### **5.1 Sustainability assessment of transport infrastructures in place**

There are studies that assess the sustainability of transport infrastructures that are already in place. This section will provide a specific example of such an assessment. Sustainability assessments of transport infrastructures in place are also incorporated in the EIA and SEA procedures through monitoring and follow-up. This can be seen in Section 5.2.

The sustainability of highways in the U.S. were evaluated in a study by Tatari and Kurmapu (2011). Multi-criteria evaluation was performed with the aid of a sustainability assessment model that uses economic, environmental and social indicators for deriving a Malmquist index, which in turn assess the change in sustainability of a highway over a certain period of time. According to Tatari and Kurmapu (2011), 29 U.S. states had improved the highway sustainability while the remaining experienced no difference or decreased highway sustainability over the examined period of time between 2000 to 2008. The states that experienced decreased highway sustainability were primary because of inefficient allocation of inputs, denoted scale inefficiency in the study. Tatari and Kurmapu (2011) state that the sustainability assessment model of existing highways does not only provide a direct assessment of the sustainability of highways. It can also be used as a source for feedback, hopefully leading to the development of more sustainable planning objectives in the future.

According to Thomopoulos and Grant-Muller (2013), the establishment of ex-post assessments are important in order to improve estimations of impact magnitudes from road transport infrastructures. Assessments performed on transport infrastructures when in place are also important since these assessments can provide feedback and lead to the development of procedures that incorporates wider impacts (Thomopoulos and Grant-Muller, 2013).

### **5.2 Specific issues in sustainability assessment of transport infrastructures**

Several studies that evaluate the performance, or effectiveness, of sustainability assessments of transport infrastructures were found through the literature review carried out in this study. According to Therivel (2010), the main assessment of the effectiveness of SEA is the

evaluation of whether it has accomplished its original aim of contributing to the protection of the environment and promotion of sustainability through the integration of sustainability issues in decision-making. There are studies that are dedicated to the identification and discussion of specific issues in connection to sustainability assessment of transport infrastructures. Examples of issues that are emphasized in such studies are incorrect estimations of environmental impacts (van Wee et al., 2005) and inadequate consideration of cumulative effects (Folkeson et al., 2013). There is also a need for a profounder understanding of indirect effects and long-term system effects that investments in transport infrastructures have on society (Jonsson and Johansson, 2006). Another emphasized issue are insufficient, or no performed, monitoring (Lundberg et al., 2010). These studies also provide suggestions for improvement that addresses the specific issues that are raised. According to Lobos and Partidario (2014), SEA still seems to be deeply rooted in EIA practices and in general the gap between SEA theory and practice seems to be large.

### **5.2.1 Environmental impact estimation**

In the study by van Wee et al. (2005), significant faults of rough methodologies used in practice for estimating environmental impacts for new transport infrastructures and modal shifts could be identified. The discussion in the study is based on data from the Netherlands and assumes that the general conclusions possibly can be relevant for all countries in the EU. The aggregation of average values employed for energy use and emissions as well as only considering direct emissions, arising from the actual use of the infrastructures, could lead to serious faults in the practice of estimating environmental impacts for new transport infrastructures (van Wee et al., 2005). The same goes for omitting possible substantial effects from indirect energy use and emissions. When larger transport infrastructure projects are considered, like highway constructions, landscape and regional perspectives together with long-term perspectives are required in impact assessments in order to properly consider ecological processes (Karlson et al., 2014). According to van Wee et al. (2005), environmental impacts are hard to quantify and monetize which often imply that these impacts are not of focus in assessments. However, at the same time environmental impacts usually create extensive opposition within the society. van Wee et al. (2005) also raise the question whether impacts on the environment can be monetized at all. The inclusion of indirect energy use and emissions, which arise from the construction, production and maintenance of transport infrastructures, might significantly affect the results of assessments (van Wee et al., 2005).

van Wee et al. (2005) provide some suggestions for improvement of environmental impact estimation. Examples of these suggestions are the inclusion of more indicators than the limited numbers that generally are used, like carbon dioxide and nitrous oxide emissions, and that many multidisciplinary researchers will be needed to achieve this. Increasing the time perspective to enhance the consideration of changes in emissions and implementing emission factors that are country-specific or region-specific are also suggested. If such data are not available the suggestion is given to investigate dominant determinants that have affected the values of the data to be used and to compare these with the determinants of the specific study area. Finally, emissions arising from the construction of infrastructures as well as indirect energy use are suggested to be included. According to van Wee et al. (2005), further research is required in connection to indirect energy use and effects in order to address the identified issues.

### **5.2.2 Cumulative effects**

Folkesson et al. (2013) consider cumulative effects in connection to transport infrastructure planning in Sweden by analysing the views of professionals engaged in EIA and SEA of roads but also of railways. Folkesson et al. (2013), furthermore performs an international literature review on the concept of cumulative effects. The general review identified some important aspects that were emphasized in the literature. An example are the crucial issue of analysing aspects in spatial and time scales that are wide enough in order to consider significant impacts in a correct way. Other issues are information sharing and stakeholder participation, education and training and the significance of environmental follow-up and feedback. Many of these issues were also emphasized in the interviews with professionals employed in Swedish transport infrastructure planning.

In contrast to the current advanced practice of cumulative effects assessment (CEA) in nations like Canada, U.S. and Australia, the cumulative effects approach is far from being applied in Sweden (Folkesson et al., 2013). Analysis of the incorporation of cumulative effects in Swedish transport infrastructure planning, through the views of professionals involved in these processes, lead to the identification of many issues and requirements for improvement and future research. Examples of identified issues are the inexistent consensus on what constitutes cumulative effects and missing linkage between science and practice in CEA. There are also issues with lacking data availability and quality at the same time as there are the great demands of data in CEAs originated from the required utilization of broad spatial and temporal scales while considering cumulative effects. Traditional ways of promoting participation, like project websites, lead to insufficient public participation. Further, the spatial and temporal scales are generally chosen with limited concern of cumulative effects. For example the spatial scale is often limited to the area that is directly affected implying that incentives to assess cumulative effects are obstructed.

Suggestions for both administrative and procedural improvement but also suggestions for further research are provided by Folkesson et al. (2013). Examples of improvement suggestions are to introduce the term cumulative effects in legislative texts and EIA/SEA guidelines as a step towards reaching consensus about the contents of the term cumulative effects. Guidelines up-dated according to the current legislation could be provided in order to aid in removing barriers for the implementation of CEA. Improved collaboration between researchers, regulators and proponents at different planning levels and procedural stages in order to link CEA science and practice are also identified as an improvement possibility. Co-ordination of data retrieval and management throughout the procedural stages of creating a baseline, monitoring and follow-up are suggested. Further it is suggested that new methods, like participatory mapping, focus groups, guided promenades, scenario techniques and network analysis are applied for public participation in transport infrastructure planning. Finally the selection of wider spatial and temporal scales that take cumulative effects into consideration are suggested. That will be encouraged by the implementation of the European Landscape Convention (ELC) that requires procedures for the inclusion of the public in the realization of landscape policies. According to Folkesson et al. (2013), knowledge support for quantification in the overall assessment of cumulative effects seems to be greatly demanded in order to bridge the knowledge gap between science and practice.

### **5.2.3 Indirect effects**

The importance of including indirect effects in consequence analysis of transport infrastructure plans and in SEAs of such plans is widely recognized (Jonsson and Johansson, 2006). However, there is a need for a deeper understanding of indirect effects arising from

investments in road transport infrastructures. More specifically, a profounder understanding of long-term system effects and how these affect the structure of the society is required according to Jonsson and Johansson (2006). The requirement of a wide perspective on indirect effects is stressed by conclusions drawn from the examination of how these effects was treated in a number of regional infrastructure plans in Sweden. According to Jonsson and Johansson (2006), only a minor fraction of these infrastructure plans covered and analysed indirect effects in a satisfactory way. According to Petäjäjärvi (2005), the focus of authorities, which are responsible for the development of infrastructures, tend to be on direct effects while indirect effects are handed over to someone else or even disregarded. The authorities also tend to focus on environmental impacts rather than socio-economic ones (Petäjäjärvi, 2005).

Possible indirect effects, arising from investments in new transport infrastructures, that are receiving specific attention in the study by Jonsson and Johansson (2006) are for example increased total volume of transport and increased share of private motorists and truck transport. Other examples of indirect effects are changed transport patterns, increased urban sprawl and altered settlement structures (Jonsson and Johansson, 2006). Investments in transport infrastructures influence the distribution of users between transport modes and in turn the choice of transport mode affect the environmental impact to various extent (Jonsson and Johansson, 2006). Investments in road infrastructures might lead to increased use of automobile and truck transport and hence increased environmental impacts since the larger disadvantages of these transport modes in connection to emissions, energy use per person-km and land use compared to public transport modes. Jonsson and Johansson (2006) identify key factors that influence indirect impacts. An example of such a key factor is the transport budget balance. The transport budget balance in turn acknowledges the connection between changes in travel time and travel costs with the possible indirect effect of increased transport volume from investment in new infrastructures.

Jonsson and Johansson (2006) suggest based on the examination of a number of regional infrastructure plans in Sweden, that an extended time perspective while considering indirect effects is of specific importance, since indirect effects usually emerge over time. More specific, scenario techniques are acknowledged as beneficial in order to consider indirect effects in transport planning processes. Because of the uncertainties connected to consequences such as indirect impacts from transport infrastructures, quantitative evaluations performed for longer time perspectives have limited value. Therefore, Jonsson and Johansson (2006) suggest that qualitative evaluations performed through scenario techniques that acknowledge key factors, which are influencing indirect impacts, might be a suitable complement.

#### **5.2.4 Stakeholder participation**

Stakeholder participation is one of the most important factors that affect to what extent SEA can have an impact on decision-making (Folkeson et al., 2013). It is also considered important with an early integration of the many views and opinions of these stakeholders (Folkeson et al., 2013). However, stakeholder participation is commonly identified as inadequate in evaluation of assessments of transport infrastructures. For example, concentrated power structures are identified by Ward (2001) as constituting a hindrance for stakeholder inclusion. According to Thomopoulos and Grant-Muller (2013), the participation of stakeholders should be increased for large transport infrastructure projects. Through the examination of the planning of urban transport systems in three case studies located in Germany, Austria and UK, Ward (2001) rejects suggestions saying that stakeholder

participation leads to expensive and inadequate transport planning. According to Ward (2001), an increased range of stakeholders participating in transport planning can imply improved problem definition and innovation diversity. However, it is also concluded that this diverse stakeholder participation is difficult to achieve and quite time-consuming. However, the establishment of agreement among stakeholders and the incorporation of new problem definitions and improvements into the planning process, which could be seen in the case studies, provide arguments for the time that was used (Ward, 2001).

In order to improve stakeholder participation, Ward (2001) suggest that the concentrated power of business élites, planners and politicians, which might hinder the inclusion of many stakeholders, could be tackled through the present democratic structures that can create and support transport forums. However, Ward (2001) conclude that a greater distribution of power in society might be necessary in the longer term.

### **5.2.5 Monitoring and follow-up**

Fischer (2001) states that current practice of SEA can only be improved if there is a clear understanding of causes and effects. Therefore, it is suggested that improved monitoring is generally required in order to realize the effects of assessments (Fischer, 2001). In a study by Lundberg et al. (2010), the environmental monitoring in Swedish regional transport infrastructure planning was assessed through interviews with representatives for this type of planning in Swedish counties. Lundberg et al. (2010) could conclude that basically no environmental monitoring was performed in practice. This were concluded although there existed frameworks and recommendations for monitoring in SEA. An explanation for the lack of monitoring could be the counties view on monitoring in SEA as a linear process rather than a iterative and continuous process. The identified gap between theory and practice in SEA in Swedish regional transport infrastructure planning can also perhaps be explained by the limited time of SEA being utilized according to Lundberg et al. (2010). Specific issues that was identified in the study by Lundberg et al. (2010) were a disincentive to participate in monitoring of planners. Planners rather concentrates on the creation of the plan and the realization of mitigation measures in the plan than on monitoring. A lack of integration between planners and environmental specialists that are performing the SEA were also identified. Another issue was the unstructured planning for monitoring and sometimes lacking monitoring possibly a result of the late initiation, usually at the end of the SEA process, of planning for monitoring. Further, issues with remedial actions that are not handled correctly were identified. Finally, issues with the long time period between the formation and execution of a plan implies a risk for loss of valuable knowledge and information perhaps due to changed conditions and personnel were highlighted.

Petäjajarvi (2005) assess the EIA follow-up of socio-economic aspects and conclude that follow-up processes of impacts in general are absent in practice. The assessment is based on Finnish EIA reports, follow-up reports and experiences from a road and bridge project in Finland. According to Petäjajarvi (2005), follow-up studies connected to highway projects are very concentrated on impacts on environmental rather than socio-economic aspects. Seldom, impacts considered significant in an EIA are incorporated in the follow-up and this deficiency arise partly as a result of the lack of guidelines for the transport infrastructure sector. Follow-up is important since the information that can be provided might lead to improved effectiveness and quality of EIA. A bridge infrastructure project that provides a fixed link to a finnish island was analyzed in a case study. The case study provides the best example of the practice of follow-up considering socio-economic effects in Finland. It could be concluded from the analysis that negative consequences can only be avoided to a great

extent through follow-up (Petäjajarvi, 2005). It could also be concluded that follow-up is required in order for the municipality to be able to make the most out of the benefits from the bridge. In the case study, a lot of the data required for the follow-up process had already been collected by different parties. According to Petäjajarvi (2005), follow-up process should not be avoided because of its costs. Identified issues are the absent recognition of follow-up processes as essential for EIA procedures, of being tools for assessment of the quality of EIAs and for improving EIA practices. According to Petäjajarvi (2005), follow-up practices are rather missing in Finnish road projects implying that the significant effects on the socio-economic development from roads are not being completely known.

In order to achieve an iterative SEA process with integrated monitoring, Lundberg et al. (2010) provides some suggestions for improvement. Examples of suggestions are that the developing practice in SEA monitoring is studied with a focus on incentives for doing monitoring. This should be done in order for these incentives to be strengthened. The work carried out by planners and environmental specialists must also be integrated. Planning for monitoring should be initiated together with the SEA scoping stage, where the purpose, what and how to monitor, timing, funding and responsibility for the monitoring should be decided. If possible, already existing monitoring programmes, like the Swedish national environmental surveillance system, should be used in order to reduce the need for resources. Further, impact levels that require remediation actions should be decided in advance and at the latest in the final SEA monitoring scheme. Swedish county administrative boards possess regional environmental quality objectives that could guide the vision of sustainability of transport plans and the objectives can be used as benchmarks for decisions regarding the need for remedial actions. Another suggestion is that the structuration of data in a “monitoring memory” could be established in order to gather all monitoring data and avoid the distribution of information in many places and in several time periods. Possibly, the monitoring results could then be used more efficiently. In order to assess practical challenges in follow-up of road projects in Finland there appears to be a demand for a simple and by the EIA practitioners accepted model (Petäjajarvi, 2005).

### **5.3 Overall effectiveness in sustainability assessment of transport infrastructures**

Other studies have evaluated the overall effectiveness of SEA and EIA applied in transport infrastructure projects. The reviewed studies in this section acknowledge several issues connected to sustainability assessment of transport infrastructures that are similar to the ones identified in Section 5.2. Examples of issues that are identified are that transport infrastructure planning carried out at a too low strategic level (Kontić and Dermol, 2015), missing identification of relevant indicators for the environmental impact assessment with the result of investigating impact magnitude instead of impact significance (Zhou and Sheate, 2011), inappropriate selection of spatial scope implying that possible environmental effects from implementation of plans are not being justified (Zhou and Sheate, 2011), insufficient transparency in different contexts (Bassi et al., 2012; Kontić and Dermol, 2015; Kis Madrid et al., 2011), inadequate public participation (Zhou and Sheate, 2011; Bassi et al., 2012; Kis Madrid et al., 2011) and limited monitoring (Kis Madrid et al., 2011).

In the study by Kontić and Dermol (2015), the strategic level of the planning of a traffic bypass around a town in Slovenia was identified as too low. For example because emphasize was put on details, which do not solve key issues. Certain elements of the SEA procedure were identified as of need for improvement. For example, CBA should be used for the optimisation of alternatives and to evaluate the effectiveness of SEA. Zhou and Sheate (2011)

examine the effectiveness of SEA in two provincial level expressway infrastructure (PLEI) network plans in China. Many issues are identified, for example no alternatives were considered and practitioners did not understand the objective of SEA.

Hildén et al. (2004) analyse the effectiveness of SEA based on 17 case studies including for example national and regional transport plans but also road corridors in member countries of the United Nations Economic Commission for Europe (UNECE). Based on the 17 case studies, Hildén et al. (2004) identifies certain conditions required to ensure the effectiveness of SEA as well as factors that contributes to improved effectiveness of SEA. There are a number of conditions that are crucial in order for the environmental assessment to influence the planning. An example is the existence of political will to use the information that can be provided by assessment. Integration of sustainability aspects in the planning as well as integration between planners and the ones that perform the assessment to establish links between different planning levels were also identified by Hildén et al. (2004) as important. Further, there should exist links between the strategic level and the project level, both in a top-down but also in a bottom-up manner. A tiered planning procedure improves communication. According to Hildén et al. (2004), correct timing is also important since if there is a mismatch between preparatory processes and the assessment process there is a risk that the possibility to affect the decision-making is gone. This is typically the case if the environmental assessment is initiated after important decisions have been made. Hildén et al. (2004) conclude based on the 17 case studies that communication are essential. However, Hildén et al. (2004) acknowledge that there are difficulties in connection to the questions of how, in what form and when the information should be transferred.

Finnveden and Åkerman (2014), analyse the Swedish national infrastructure plan for 2010-2021 and the planning for a major road investment for a bypass in Stockholm. Finnveden and Åkerman (2014), conclude that long-term sustainability aspects are absent in the planning processes for the plans and that these do not support the Swedish transport policy aiming at sustainable transport. The recommendation of Bypass Stockholm by the Swedish road administration did not only contradict the recommendations from the Swedish environmental protection agency (SEPA) (Finnveden and Åkerman, 2014). The Bypass Stockholm was also recommended although this alternative was not the optimal one from an environmental perspective. According to Finnveden and Åkerman (2014), the long-time expectation of planners that the road would be built might have led to the suggestion of the bypass Stockholm despite the lack of transparent arguments for it being the best alternative. Although the responsibility of both SEPA and the County Administrative Board of Stockholm their opinions had limited influence. The planning processes are in need of substantial improvements to reflect the Swedish transport policy objectives of sustainable transport (Finnveden and Åkerman, 2014).

#### **5.4 The effectiveness of the SEA Directive**

The effectiveness of the SEA Directive and how it is applied in member states in general was evaluated in a study by EC (2009a). The effectiveness was evaluated by assessing to which degree planning and programmes had been influenced by environmental considerations, which is integrated in the decision-making through SEA (EC, 2009a; EC, 2009b). The extent to which the application of SEA had implied adjustments to plans and programmes also provided a base for the assessment of the effectiveness. In the study by EC (2009a), it could be concluded that the effectiveness of SEA varied between EU member states depending on institutional and legal arrangements. The study stated that SEA is at its infancy and identified issues with for example identification of the appropriate scale of data, level of detail in the

assessment, identification of alternatives and problems with consultations that do not take place in the early stage of the project as well as issues with monitoring. Many of the issues in EC (2009a) were also recognized in the studies of the effectiveness of transport infrastructure projects specifically, see Section 5.2 and 5.3.

## 6 Conclusions

A literature review has been performed in order to identify the best practices together with issues and knowledge gaps associated with these practices in sustainability assessment of transport infrastructures. Environmental impact assessment (EIA), Strategic environmental assessment (SEA), Cost-benefit analysis (CBA), Multi-criteria analysis (MCA) and Life-cycle analysis (LCA) are all examples of methodologies that are used in sustainability assessments of transport infrastructures. CBA, MCA and LCA are also often incorporated in the procedures of EIA and SEA. SEA acknowledges limitations of EIA and introduces wider perspectives to consider sustainability aspects more properly. However, sustainability assessment of transport infrastructures performed with SEA that considers sustainability aspects sufficiently and realizes strategic planning of these complex systems, seems to be at its infancy. Several issues and knowledge gaps were also identified in connection to these practices. Frequently identified issues and knowledge gaps connected to sustainability assessment of transport infrastructures are presented in Table 2.

**Table 2: Issues and knowledge gaps in connection to sustainability assessment of transport infrastructures.**

Issues and knowledge gaps	
<i>Wider perspectives</i>	<ul style="list-style-type: none"> <li>• Inappropriate selection of spatial and temporal scales leading to inadequate consideration of cumulative effects</li> <li>• Need for a deeper understanding of indirect effects, long-term system effects and effects on the structure of society</li> <li>• Wider spatial and temporal scales, consider cumulative impacts and indirect effects</li> <li>• Omission of indirect emissions leading to incorrect estimation of environmental impacts</li> <li>• Planning carried out at a too low strategic level so that details, which do not solve the key issues, are emphasized</li> </ul>
<i>Stakeholder participation</i>	<ul style="list-style-type: none"> <li>• Inadequate stakeholder participation initiated after decisions are already made</li> <li>• Requirement of incorporation of more stakeholders</li> </ul>
<i>Collaboration and communication</i>	<ul style="list-style-type: none"> <li>• Between procedural stages, stakeholders, researchers, planners</li> <li>• Linking procedural stages</li> <li>• Combine planning procedures with planning in other fields like land use, urban development and energy</li> </ul>
<i>Combining knowledge</i>	<ul style="list-style-type: none"> <li>• Utilizing knowledge that already exist and could be applicable from other fields</li> </ul>
<i>Monitoring and follow-up</i>	<ul style="list-style-type: none"> <li>• Insufficient monitoring of socio-economic but also environmental aspects</li> </ul>

Through addressing the issues and knowledge gaps in Table 2, improvements and strategies for more sustainable transport infrastructures could hopefully be achieved. The issues and knowledge gaps in Table 2 further provide suggestions for what could be addressed by research and possibly in a research project in connection to sustainability assessment of transport infrastructures.



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