Assessing Transport Infrastructure Sustainability

Literature Review of Practices in Sustainability Assessment of Transport Infrastructures with the Identification of Issues and Knowledge Gaps

Anna Furberg[1], Sverker Molander[1], Holger Wallbaum[2]
[1]*Division of Environmental System Analysis*, Department of Energy and Environment, CHALMERS UNIVERSITY OF TECHNOLOGY
[2]Department of Civil and Environmental Engineering, CHALMERS UNIVERSITY OF TECHNOLOGY

Summary

In this study we report a review of scientific literature, published from the year 2000 to 2014, aiming to identify the current best practices in sustainability assessment, including planning, of transport infrastructures together with current issues and knowledge gaps. Sustainability assessments of transport infrastructures are slowly increasing around the world and the practices vary considerably. Current applied methods rely basically on Environmental impact assessment (EIA) or Strategic environmental assessment (SEA) procedures, which in turn often contain one or more procedures such as Cost-benefit analysis (CBA), Multi-criteria analysis (MCA) and Life cycle analysis (LCA). In several countries legal frameworks exist for sustainability assessment of transport infrastructures, for instance the EIA and SEA Directives in Europe. However, limitations of EIA and SEA are acknowledged in literature, although a few studies report improved sustainability assessments. Suggestions are also made in literature to introduce wider perspectives in order to consider sustainability aspects more properly, e.g. the inclusion of social indicators. Assessments aiming at the consideration of sustainability aspects and influencing the strategic planning of these complex systems are rare and methods are in their infancy. Key issues and knowledge gaps that are in need of being further addressed by research include the requirement to cover wider spatial and temporal scales, the consideration of cumulative and indirect effects and a more effective incorporation of stakeholders. Other highlighted issues are inadequate monitoring of project outcomes and the general lack of combination of knowledge from different knowledge fields.

Keywords Sustainability assessment, Transport, Infrastructure, Strategic environmental assessment

Introduction

The size and complexity of megaprojects, such as motorways, are constantly increasing (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. As these 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 (ERTRAC, 2010; EC, 2011).

The planning and construction of transport infrastructures takes many years and they last for decades, implying that the decisions made today will determine the transport in many years ahead (EC, 2011; van Wee et al., 2005). Although many transport infrastructure projects are constructed and there is a lot of published research in this topic, a disagreement exists on the actual benefits from transport infrastructure investments (Thomopoulos and Grant-Muller, 2013). In many cases forecasted returns from such investments are not realized and the validity of investments might be questioned (ECA, 2013; Miceviciene, 2012; Flyvbjerg, 2014). 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; EC, 2011). The management of megaprojects and the selection of the appropriate project alternative are crucial since there are so many resources involved in these projects. Therefore the consideration of economic, social and environmental impacts of these projects together with practices of informing policy, practice and public debate about these very costly projects has never been more important (Flyvbjerg, 2014). In order to manage the complexity of transport infrastructures and the multitude of trade-offs in these systems, there is a need for procedures to be improved. There seems to be a need for sustainability assessment. This study addresses the acknowledged requisite of improved consideration of environmental, economic and social aspects in connection to transport infrastructure projects. This is done with the aim to identify current best practices with associated issues and knowledge gaps.

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 the state-of-the-art in sustainability assessments, with EIA, SEA and MCA, practiced in the countries of England, Australia, Canada and South Africa. Concerning practices in sustainability assessment of transport infrastructure projects specifically, there exist many recent studies of EIA, SEA, CBA, MCA and LCA.

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 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, for example through the EIA Directive (Thorne et al., 2014; Arts and Faith-Ell, 2012; EU, 2012).

Strategic Environmental Assessment (SEA) The development of SEA, which is widely applied, has its origins in claims of the inability of the EIA process to consider sustainability aspects (Thorne et al., 2014; 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. 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). Other shortcomings of project level EIA that the SEA procedure wants to address, are the limited effect on decision-making, the compact timescale, inappropriate consideration of cumulative effects and insignificant monitoring (Zhou and Sheate, 2011). SEA identifies the best options in the early planning stage and incorporates strategic thinking into decision-making, while EIA assess the effects of projects in the later stage (Arce and Gullón, 2000; EC, 2009; Partidario, 2012). Further, SEA considers project alternatives, broadens the spatial and temporal perspectives and hence works in a more proactive manner rather than the reactive one of EIA (Arce and Gullón, 2000). These benefits of SEAs in connection to transport infrastructure projects are similar to the general benefits of SEA described by Therivel (2010).

Cost-Benefit Analysis (CBA) Currently, CBA is the most widely used approach for the assessment of transport in Europe. Both funding instruments and practice promote the utilization of this tool (Thomopoulos and Grant-Muller, 2013). Although its wide application, many limitations have been identified of CBA in considering social, environmental and strategic issues. These limitations are associated with the fact that all impacts should be monetized in CBA, which is not possible in many cases. van Wee (2012) reflects on MCA as an alterative and complement to CBA in order to address the difficulty of CBA to include impacts that are not easily monetized, like nature effects, specific social effects and distribution effects.

Multi-Criteria Analysis (MCA) MCA is 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). Instead, MCA integrates information about impacts with the views and opinions of stakeholders and decision-makers (Geneletti, 2005). However, 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 potentially complex and time-consuming, but at the same time MCA improves transparency since preferences of the decision-makers must be expressed (Thomopoulos and Grant-Muller, 2013).

Life-Cycle Analysis (LCA) There are many studies that focus on specific sustainability issues and how these can be handled connected to transport infrastructures on a more detailed level. Examples are studies that focus on road pavement, which typically utilizes LCA (Santero et al., 2011; Gschösser and Wallbaum, 2013). According to Zinke et al. (2012) many inaccuracies and assessment difficulties exist for LCA, especially in connection to social issues that can be quite difficult to assess quantitatively. Santero et al. (2011) emphasize expanded system boundaries and broadened study scopes for LCA in connection to pavement, and argue that this is required to comprehensively quantify environmental impacts and to guide sustainability purposes in an effective way. The identified limitations of LCA leads to considerations regarding the potential of LCA to properly address sustainability issues in connection to transport infrastructures. However, 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 (Stripple and Erlandsson, 2004).

Lessons to be learned?

Several issues and knowledge gaps were identified in this study in connection to sustainability assessments of transport infrastructures in general, but also in studies of the overall effectiveness for these assessments. The identification of several issues and knowledge gaps do lead to the insight that there are several lessons to be learned.

Incorrect estimation of environmental impacts Significant faults are identified by van Wee et al. (2005) of rough methodologies used in practice for estimating environmental impacts for new transport infrastructures. Some examples are the aggregation of average values, which are not country- or region-specific, employed for energy use and emissions as well as only considering direct emissions arising from the actual use of the infrastructures. Environmental impacts are also hard to quantify and monetize, which often imply that these impacts are not focused in assessments despite the fact that they usually create extensive opposition within the society (van Wee et al., 2005). Wider perspectives, both spatial and temporal, are emphasized in literature as required in order to consider environmental impacts properly (Karlson et al., 2014; Zhou and Sheate, 2011). Further, according to Lobos and Partidario (2014) it is essential that uncertainties and dynamics of complex systems are addressed in assessments and predictions. Thorne et al. (2014) identified that project-by-project analysis led to underestimation of environmental impacts. While Lobos and Partidario (2014) can conclude that SEA still seems to be deeply rooted in EIA practices and in general the gap between SEA theory and practice seems to be large. In order for environmental assessments to influence planning, it is important that decision-makers want to use the provided information and that sustainability aspects are integrated in planning (Hildén et al., 2004). It is also important with the communication between planners and assessors and that links between different planning levels are established. Several authors acknowledge the need for combining transport infrastructure planning with other fields like 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; McCalley et al., 2010).

Inadequate consideration of cumulative effects A crucial issue in connection to assessments of transport infrastructures is to analyse aspects in spatial and time scales that are wide enough (Folkeson et al., 2013; Arce and Gullón, 2000). Implying that spatial and time scales should be chosen wide enough in order to consider significant impacts in a correct way and to incorporate sustainability in these large and complex projects. Adequate consideration of cumulative impacts is also connected to the issue of proper information sharing and stakeholder participation, education and training and environmental follow-up and feedback. Suggestions that might lead to administrative and procedural improvements are to enhance collaboration between researchers, regulators and proponents at different planning levels and procedural stages in order to link cumulative effects assessment science and practice (Folkeson et al., 2013). Co-ordination of data retrieval and management throughout the procedural stages of creating a baseline, monitoring and follow-up could also lead to improvements. 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 (Folkeson et al., 2013).

Limited understanding of indirect effects The importance of including indirect effects in consequence analysis of transport infrastructure plans, like in SEAs of such plans, is widely recognized (Jonsson and Johansson, 2006). Nevertheless, there is a need for a deeper understanding of indirect effects arising from investments in road transport infrastructures and how long-term system effects in turn affect the structure of society. In the studies by Finnveden and Åkerman (2014) and Jonsson and Johansson (2006) it could be concluded that long-term sustainability aspects were absent in planning processes and that only a minor fraction of the studied infrastructure plans covered and analysed indirect effects, in a satisfactory way. Authorities, which are responsible for the development of infrastructures, tend to focus on direct effects rather than indirect ones and on environmental impacts rather than socio-economic ones (Petäjäjärvi, 2005). According to Zinke et al. (2012), research connected to social aspects is still in its infancy, especially when infrastructures and bridges are considered. An extended time perspective while considering indirect effects is of specific importance since these effects usually emerge over time (Jonsson and Johansson, 2006). Further, due to uncertainties connected to consequences such as indirect effects, quantitative evaluations performed over longer time perspectives might have limited value and qualitative evaluations using scenario techniques might therefore be a suitable complement.

Restricted stakeholder participation Stakeholder participation is one of the most important factors that affect to what extent SEA can have an impact on decision-making and an early integration of the many views and opinions of these stakeholders is significant (Folkeson et al., 2013). However, stakeholder participation is commonly identified as inadequate in evaluations of transport infrastructure assessments and the public participation as insufficient (Zhou and Sheate, 2011; Bassi et al., 2012; Kis Madrid et al., 2011). 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. In the study by Kontić and Dermol (2015), the strategic level of transport infrastructure planning with SEA was identified as too low. However, there are new approaches emerging in the recent practice of transport infrastructure developments with increased collaboration between governmental, public and private stakeholders (Arts and Faith-Ell, 2012). Governance approaches should be integrated in order to enable transfer of information, communication, and learning from experience as well as an environmental management that is adaptive. Although diverse stakeholder participation is difficult to achieve and quite time-consuming, Ward (2001) rejects suggestions saying that stakeholder participation leads to expensive and inadequate transport planning. According to Ward (2001) the establishment of agreement among stakeholders and the incorporation of improved problem definitions, innovation diversity and improvements into the planning process through increased range of stakeholders participation do provide arguments for the time consumed.

Insufficient or absent monitoring and follow-up The current practice of SEA can only be improved if there is a clear understanding of causes and effects according to Fischer (2001). In general, improved monitoring is required in order to realize the actual effects of the proposals made in these assessments (Fischer, 2001). In some studies, monitoring was identified as limited and in others basically no environmental monitoring or follow-up of socio-economic effects were performed in practice (Kis Madrid et al., 2011; Lundberg et al., 2010; Petäjäjärvi, 2005). In order to achieve an iterative SEA process with integrated monitoring, Lundberg et al. (2010) suggests that incentives for monitoring is studied in efforts to strengthen them. Further, 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.

Conclusions

There is in general a need for wider perspectives in the assessments performed. EIA, SEA, CBA, MCA and LCA are all examples of methodologies that are used in sustainability assessments of transport infrastructures and CBA, MCA and LCA are 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 seems to be at its infancy when considering the strategic planning of these complex systems. The many identified issues and knowledge gaps connected to sustainability assessment of transport infrastructures are summarized in Table 1.

Table 1: Issues and knowledge gaps in connection to sustainability assessment of transport infrastructures that were identified in reviewed literature.

Issues	Knowledge gaps
Wider perspectives	• Wider spatial and temporal scales are needed e.g. to consider cumulative impacts and indirect effects properly • Need for a deeper understanding of long-term system effects and effects on the structure of society • Planning carried out at a too low strategic level
Stakeholder participation	• Inadequate stakeholder participation, initiated after decisions are already made • Requirement of incorporation of more stakeholders
Collaboration and communication	• Between procedural stages, stakeholders, researchers and planners in different fields like land use, urban development and energy
Combining knowledge	• Utilizing knowledge that already exist and could be applicable from other fields
Monitoring and follow-up	• Insufficient monitoring of socio-economic but also environmental aspects

Acknowledgement

The authors would like to acknowledge the Norwegian Public Roads Administration (NPRA) for supporting this study.

References

Arce R and Gullón N. (2000) The application of Strategic Environmental Assessment to sustainability assessment of infrastructure development. *Environmental Impact Assessment Review* 20: 393-402.

Arts J and Faith-Ell C. (2012) New governance approaches for sustainable project delivery. In: Papaioannou P (ed) *Transport Research Arena 2012.* 3239-3250.

Bassi A, Howard R, Geneletti D, et al. (2012) UK and Italian EIA systems: A comparative study on management practice and performance in the construction industry. *Environmental Impact Assessment Review* 34: 1-11.

Bond A, Morrison-Saunders A and Howitt R. (2013) Sustainability assessment - Pluralism, practice and progress. In: Glasson J (ed) *The Natural and Built Environment Series.* New York: Routledge.

EC. (2009) *(European Commission) Report from the commission to the council, the european parliament, the european economic and social committee and the committe of the regions - On the application and effectiveness of the Directive on Strategic environmental assessment (Directive 2001/42/EC)*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009DC0469&from=EN [Accessed 2014-09-24].

EC. (2011) *(European Commission) Roadmap to a single European transport area - Towards a competitive and resource efficient transport system*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN [Accessed 2014-09-17].
ECA. (2013) *(European Court of Auditors) Are EU cohesion policy funds well spent on roads? Special Report No 5*. Available at: http://www.eca.europa.eu/Lists/ECADocuments/SR13_05/SR13_05_EN.PDF [Accessed 2014-10-21].
ERTRAC. (2010) *(European Road Transport Research Advisory Council) ERTRAC Strategic research agenda 2010 - Towards a 50% more efficient road transport system by 2030 Executive summary*. Available at: http://www.ertrac.org/uploads/documentsearch/id21/ERTRAC_SRA_2010.pdf [Accessed 2014-09-17].
EU. (2012) *(European Union) Directive 2011/92/EU of the European parliament and of the council on the assessment of the effects of certain public and private projects on the environment*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0092&from=EN [Accessed 2014-09-18].
Finnveden G and Åkerman J. (2014) Not planning a sustainable transport system. *Environmental Impact Assessment Review* 46: 53-57.
Fischer TB. (2001) Practice of environmental assessment for transport and land-use policies, plans and programmes. *Impact Assessment and Project Appraisal* 19: 41-51.
Flyvbjerg B. (2014) What you should know about megaprojects and why: An overview. *Project Management Journal* 45: 6-19.
Folkeson L, Antonson H and Helldin JO. (2013) Planners' views on cumulative effects. A focus-group study concerning transport infrastructure planning in Sweden. *Land Use Policy* 30: 243-253.
Fundingsland Tetlow M and Hanusch M. (2012) Strategic environmental assessment: The state of the art. *Impact Assessment and Project Appraisal* 30: 15-24.
Geneletti D. (2005) Multicriteria analysis to compare the impact of alternative road corridors: a case study in northern Italy. *Impact Assessment and Project Appraisal* 23: 135-146.
Gschösser F and Wallbaum H. (2013) Life cycle assessment of representative swiss road pavements for national roads with an accompanying life cycle cost analysis. *Environmental Science and Technology* 47: 8453-8461.
Hildén M, Furman E and Kaljonen M. (2004) Views on planning and expectations of SEA: The case of transport planning. *Environmental Impact Assessment Review* 24: 519-536.
Jonsson DK and Johansson J. (2006) Indirect effects to include in strategic environmental assessments of transport infrastructure investments. *Transport Reviews* 26: 151-166.
Karlson M, Mörtberg U and Balfors B. (2014) Road ecology in environmental impact assessment. *Environmental Impact Assessment Review* 48: 10-19.
Kis Madrid C, Hickey GM and Bouchard MA. (2011) Strategic environmental assessment effectiveness and the Initiative for the Integration of Regional Infrastructure in South America (IIRSA): A multiple case review. *Journal of Environmental Assessment Policy and Management* 13: 515-540.
Kontić B and Dermol U. (2015) Confronting reality in strategic environmental assessment in Slovenia — Costs and benefits. *Environmental Impact Assessment Review* 50: 42-52.
Lobos V and Partidario M. (2014) Theory versus practice in Strategic Environmental Assessment (SEA). *Environmental Impact Assessment Review* 48: 34-46.
Lundberg K, Balfors B, Folkeson L, et al. (2010) SEA monitoring in Swedish regional transport infrastructure plans - Improvement opportunities identified in practical experience. *Environmental Impact Assessment Review* 30: 400-406.
McCalley J, Ibanez E, Gu Y, et al. (2010) *National Long-Term Investment Planning for Energy and Transportation Systems*.
Miceviciene D. (2012) Transport Infrastructure Development in the Context of Sustainable Development: Towards Evidence Base. *Changes in Social and Business Environment: Proceedings of the 4th International Conference.* 138-142.
Mörtberg U, Haas J, Zetterberg A, et al. (2013) Urban ecosystems and sustainable urban development-analysing and assessing interacting systems in the Stockholm region. *Urban Ecosystems* 16: 763-782.
Partidario M. (2012) *Strategic Environmental Assessment Better Practice Guide - Methodological guidance for strategic thinking in SEA*. Available at: http://www.iaia.org/publicdocuments/special-publications/SEA Guidance Portugal.pdf [Accessed 2014-09-16].
Petäjäjärvi R. (2005) Follow-up of socio-economic aspects in a road project in Finland. *Impact Assessment and Project Appraisal* 23: 234-240.
Santero NJ, Masanet E and Horvath A. (2011) Life-cycle assessment of pavements. Part I: Critical review. *Resources, Conservation and Recycling* 55: 801-809.
Stripple H and Erlandsson M. (2004) *Methods and possibilities for application of life cycle assessment in strategic envrionmental assessment of transport infrastructures*. Available at: http://www3.ivl.se/rapporter/pdf/B1661.pdf [Accessed 2014-10-23].
Therivel R. (2010) *Strategic Envrionmental Assessment in Action,* Second Edition. London, UK, and Washington DC, USA: Earthscan.
Thomopoulos N and Grant-Muller S. (2013) Incorporating equity as part of the wider impacts in transport infrastructure assessment: An application of the SUMINI approach. *Transportation* 40: 315-345.
Thorne JH, Huber PR, O'Donoghue E, et al. (2014) The use of regional advance mitigation planning (RAMP) to integrate transportation infrastructure impacts with sustainability; A perspective from the USA. *Environmental Research Letters* 9.
van Wee B. (2012) How suitable is CBA for the ex-ante evaluation of transport projects and policies? A discussion from the perspective of ethics. *Transport Policy* 19: 1-7.
van Wee B, Janse P and van den Brink R. (2005) Comparing energy use and environmental performance of land transport modes. *Transport Reviews* 25: 3-24.
Ward D. (2001) Stakeholder involvement in transport planning: Participation and power. *Impact Assessment and Project Appraisal* 19: 119-130.
Yigitcanlar T and Dur F. (2010) Developing a sustainability assessment model: The sustainable infrastructure, Land-use, environment and transport model. *Sustainability* 2: 321-340.
Zhou K-Y and Sheate WR. (2011) Case studies: Application of SEA in provincial level expressway infrastructure network planning in China — Current existing problems. *Environmental Impact Assessment Review* 31: 521-537.
Zinke T, Ummenhofer T, Pfaffinger M, et al. (2012) The social dimension of bridge sustainability assessment - Impacts on users and the public. *Bridge Maintenance, Safety, Management, Resilience and Sustainability*: 1836-1843.