Transportation Research Part D 46 (2016) 207–228

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Design and evaluation of railway corridors based on spatial ecological and geological criteria

M. Karlson *, C.S.J. Karlsson, U. Mörtberg, B. Olofsson, B. Balfors

Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden

ARTICLE INFO

Article history:
Available online 15 April 2016

Keywords:
Multi-criteria analysis
Railroad planning
Decision support
Biodiversity
Environmental impact assessment
Strategic environmental assessment

ABSTRACT

Transport infrastructure is closely linked to several sustainability issues of main policy relevance, and significant impacts on biodiversity as well as resource use and construction costs relate to the corridor design and location in the landscape. The aim of this study was to develop methods for railway corridor planning, in which corridor design and location would be based on important ecological and geological sustainability criteria. The method, an MCA framework including both spatial and non-spatial MCA, was demonstrated on a railway planning proposition in an urbanising area north of Stockholm, Sweden. Alternative spatial alignments for 6 railway corridors were derived based on criteria representing biodiversity, resource efficiency and costs, developed from ecological and geological knowledge, data and models. The method identified a study area specific positive synergy between ecological and geological sustainability criteria. The evaluation part of the methodology could furthermore identify uncertainties in the input data and assumptions and conflicts between ecological criteria. In order to arrive at a well-informed decision support system, the criteria as well as the decision rules employed could be further elaborated. Other relevant sustainability issues would also need to be integrated, such as cultural landscapes, recreation, and other ecosystem services. Still, arriving at a corridor design informed by the ecological and geological conditions in the planned area, as demonstrated by this study, could improve the sustainability performance of transport infrastructure planning.

Introduction

Transport infrastructure is closely linked to several sustainability issues of major policy relevance, including economic growth, resource and energy efficiency, and biodiversity. Transport infrastructure investments are widely considered to promote positive economic development even though some research question that belief (Melo et al., 2013; Banister and Thurstain-Goodwin, 2011; Banister and Berechman, 2001; Rietveld, 1994). However, transport infrastructure networks are as well associated with environmental problems (Forman et al., 2003; Trombulak and Frissell, 2000; Spellerberg, 1998), and traffic volumes increasing along with GDP is considered unsustainable to the degree that the need to decouple economic growth from growth in transportation demand was explicitly stated in the EU Sustainable Development Strategy (European Union Commission, EC, 2009; van Elburg, 2003).

* Corresponding author at: Division of Land and Water Resources Engineering, KTH, SE-10044 Stockholm, Sweden. Tel.: +46 8 790 60 00; fax: +46 (0) 8 411 07 75.

E-mail address: mkarlso@kth.se (M. Karlson).

http://dx.doi.org/10.1016/j.trd.2016.03.012
1361-9209/

The construction of transport infrastructure involves substantial use of raw materials and energy, which contributes to GHG emissions and puts high pressure on resources, and may in the long run threaten the security of supply. Transport systems are thus among the policy areas that need to be involved in a transition to a resource-efficient and low-carbon economy in Europe (EC, 2011). Transportation infrastructure also impacts on biodiversity, a crucial component of sustainable development, as pointed out in recent research (Steffen et al., 2015) as well as in the 2009 review of the EU Sustainable Development Strategy (EC, 2009) and other (European Environment Agency, 2009; Convention on Biological Diversity, 2010).

In 2012, the EU-commission adopted a Resolution to the EU Biodiversity Strategy to 2020 (European Parliament, 2012), which explicitly recognizes, among other topics, infrastructure, urbanization and physical intervention in the landscape as significant drivers for the fragmentation of ecosystems and habitats. The Resolution also states the need to step up the use of Environmental Impact Assessments (EIAs), Strategic Environmental Assessments (SEAs) and other instruments to combat further biodiversity loss. Furthermore, the need for a multidisciplinary research approach was recognized when it comes to biodiversity, as well as the need for science-based policies in sustainable management of ecosystems and natural resources.

Environmental impacts of transport infrastructure, negative as well as some positive, are well documented. Roads and railways cause more or less permanent alterations to hydro-geological patterns in the landscape, with consequential changes in run-off, sedimentation and water quality (Coffin, 2007; Forman et al., 2003; Spellerberg, 1998; Trombulak and Frissell, 2000). Furthermore, transport infrastructure causes loss, fragmentation and degradation of natural habitats, adds new habitat, introduces barriers to movements, and increases wildlife mortality; all of which affects ecological processes related to population dynamics, e.g. colonization, extinction and genetic exchange (Dixo et al., 2009; Holderegger and Di Giulio, 2010). The impacts of these changes can be both positive and negative; however, overall, these impacts have been pointed out as major threats to biodiversity (Benítez-López et al., 2010; Coffin, 2007; Eigenbrod et al., 2009; Forman et al., 2003; Spellerberg, 1998; Trombulak and Frissell, 2000). Road mortality can become a biodiversity concern above certain levels (McCall et al., 2010; Mumme et al., 2000), and in addition, fatal vehicle–large animal collisions bring about considerable socio-economic expenses (Sullivan, 2011).

From a biodiversity perspective, crucial negative effects are related to issues such as the location of the road or railway in the landscape, the severity of its barrier effects, and its utilization and management (Karlson et al., 2014). There is still great potential for avoiding much of these impacts through well-informed road/railway corridor planning; as well as for mitigation measures such as fauna passages and habitat restoration, and compensation (Villarroya et al., 2014; Corlatti et al., 2009; van der Ree et al., 2007). When it comes to corridor planning, biodiversity impacts are to a great extent determined by its spatial alignment in the landscape. In a given landscape, some areas would be more suitable for construction while others would be less, according to the spatial distribution of biodiversity components in the landscape, such as habitats and populations that could be more or less significant from a biodiversity point of view. In addition, the effects of a poorly located road/railway with very low permeability for wildlife movements would also be difficult to mitigate, at least with reasonable costs.

Similarly, from a resource-efficiency point of view, each landscape has a particular distribution of resources that could potentially be used for transport infrastructure construction, and a given topology which delineates suitable and less suitable corridor locations from a constructional point of view. Adequate consideration of the geological conditions before construction could reduce cost considerably (Loorents, 2006). The subsurface characteristics, such as soil type and soil depth, could have an adverse effect on the infrastructural project through the costs coupled with ground stabilization measures (Loorents, 2006), as well as material transport. Soils differ in their capability of frost action, swelling and shrinkage (O'Flaherty, 2002) which, if not anticipated, could increase the maintenance frequency due to failures. The soil characteristics could also increase the total cost of the construction project or result in an increased need to excavate or fill different sections along a route. Excavations increase the amount of material generated from a construction site which could, if the material cannot be used within the project, require further material transport.

Considerable resources are commonly allocated for transport infrastructure construction and maintenance, for instance, the Swedish funding for infrastructure investments decided in the national transport plan for the years 2014–2025 amounts to 56.9 billion EUR (Ministry of Enterprise and Innovation, 2014). In view of this, the achievement of sustainability goals concerning economy, efficient use of natural resources, and biodiversity should benefit from a planning process in which road and railway corridor design would be informed by geological and ecological suitability on a landscape level, and eventual synergies between these aspects.

EIA and SEA are planning instruments with the potential to highlight these sustainability aspects of roads and railways, and bring them into the planning process. However, recent studies indicate that environmental assessment of transport infrastructure planning rely on methods that rarely manage to fully account for the above mentioned ecological aspects, and that the most prominent impacts on biodiversity, habitat loss and fragmentation, are still not effectively addressed (Karlson et al., 2014; Geneletti, 2006; Gontier et al., 2006; Byron et al., 2000; Thompson et al., 1997). In a sample of environmental reports reviewed in Karlson et al. (2014), the documents conveyed no indication that corridor alignment in the landscape would be informed about the distribution of ecological and geological resources of importance to sustainable development. Rather, impacts on environmental, cultural historical and aesthetical landscape attributes were assessed based on corridors designed before the EIA or SEA processes were initiated (Karlson et al., 2014). There are however good opportunities to integrate these aspects in corridor design in the pre-EIA or SEA planning process (Fig. 1), thus potentially avoiding or minimizing environmental impacts, unnecessary construction costs and costly mitigation measures, through an increased use of contemporary spatial ecological and geological models.