EIMI – A method to evaluate Environmental impacts of infrastructure

Author:
Leena Korkiala-Tanttu
Senior research Scientist
VTT Technical Research Centre of Finland
Lämpömiehenkuja 2 C
Otaniemi
Post Box 1000
02044VTT
Finland
Tel. +358 20 722 4943
Fax. +358 20 722 7060
E-mail: leena.korkiala-tanttu@vtt.fi

ABSTRACT

The main objective of the "Environmental values and eco-indicators in road construction" study (2004-2006) was to develop a method to estimate the environmental impacts of infrastructure construction taking in to account the different stages including planning, design, construction, maintenance and operation. The infrastructure in question was restricted to include roads, railways, streets and water ways.

Environmental impacts can be described in many ways. In the study, the objective was to develop a life cycle based assessment method to estimate environmental impacts. The method EIMI (Environmental IMpact of Infrastructures) was designed so that it could be implemented in the design, building, maintenance and management of infrastructure. The method includes all remarkable factors of the environmental impact categories and corresponding environmental stressors.

The project developed a draft for an assessment method. With the help of the method the total environmental impact is described in terms of eleven environmental impact categories. The categories are indicated with the help of environmental stressors. The method includes indicator descriptions, their potential measuring methods and limit values. Some stressors are described qualitatively and with the help of classification.

The EIMI method is a systematic and simplified method to estimate environmental impacts. The method is powerful when different alternatives are compared with one other. However, the quality of the result depends on the assessment method itself - especially the comprehensiveness of impact categories and the validity of the weighting. In addition, the quality of the result depends of the care taken in the assessment procedure and especially on the accuracy of data collection. The method includes subjective yet transparent weightings, which may be chosen to meet one's goals.

1. INTRODUCTION

The research project 'Environmental Values and Ecoindicators of the Infra Construction' was launched at the end of 2004 as part of the INFRA Technology Programme of the Finnish Funding Agency for Technology and Innovation (TEKES). The research was carried out by VTT and the Finnish Environment Institute (SYKE) and funded by TEKES, the Finnish Road Administration, the Finnish Road Enterprise, the Finnish Rail Administration, the Public Works Department of the City of Helsinki, the Central Association of Earth moving Contractors in Finland, SYKE and VTT.

The main goal of the study was to develop a method for assessing the environmental impact of infra construction projects and for considering the assessment data at different stages of the construction process. In this context, the term 'infra' or 'infrastructure' referred to roads and streets, railways and waterways. The project team proposed a set of ecoindicators to be used as a tool for construction design, procurement, implementation and management. The structure of the assessment method allows it to be used at different levels of infra construction on different sites. The team prepared a description of each indicator, including potential measuring methods and limit values. Some environmental stressors were such that only qualitative or indirect indicators were possible. The assessment method can be used to determine the total impact value of a construction project or for the use or maintenance of the infrastructure. Other components of an economic life cycle – functionality and economic efficiency – will be studied in other projects.

Indicators for ecologically sustainable construction and transport are needed to support decision making. Many decisions that have a significant impact on the outcome have to be made at the initial stages of the planning (Figure 1), at which time there is little detailed information on the impacts of the project. The scope of a project may be extensive or its principal impacts may be indirect; furthermore, projects are seldom identical. For these reasons it is important to develop an indicator method that makes it possible to assess and compare the impacts. Furthermore, various procurement processes in infra construction require an open indicator method that can be adapted to different needs.

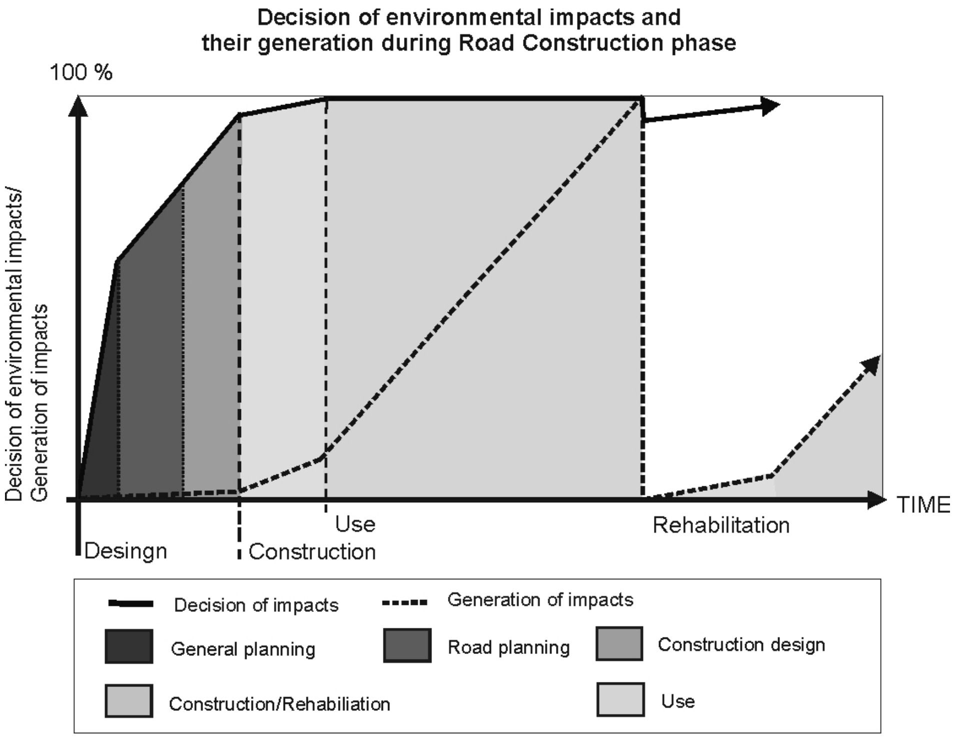

Figure 1. The principle of generation of environmental impacts and decision of environmental impacts in different phases of infrastructure process.

The following studies and reports provided the background research for the ecoindicators project:

- The 'Life Cycle Systematics in the Infrastructure Sector' project' (Lehmus et al. 2002); the bibliography review carried out in connection with the project addressed the status of development of life cycle management methods in Finland and abroad.
- Finnra's life cycle and other environmental reviews
- The 'Pilot projects for life cycle studies in road maintenance' project – testing the introduction of life cycle thinking (Korkiala-Tanttu et al. 2005)
- The Finnish Road Enterprise's life cycle reviews
- International reports (UK and the Swedish road authority)
- National and international indicator studies in transportation research

The first sub-target of the study was to lay the foundation for the development of a tool that clients, contractors and materials suppliers could use to assess the environmental impacts of infra construction projects. Environmental impacts will be emphasised in future contracts, which requires reliable, industry-approved indicators for their assessment and monitoring. Compared with housing construction, stressors related to land use and soil pose a special challenge.

Another sub-target was to describe the various stressors and list them in order of importance. Measurable variables, which could also be converted into life cycle costs where applicable, would be used as indicators as far as possible.

The assessment method was designed to serve goal-setting, monitoring and evaluation of results on five levels: (1) the client's goal-setting, (2) use of infrastructure, (3) various project design stages, project implementation and management, (4) making, assessing and comparing orders, and (5) assessment and targets on a company level. Besides the first and fourth levels, construction design, construction and management were assigned the most weight. The assessment method created also serves the purpose of defining potential bonuses or penalties related to environmental characteristics. The assessment method can be used as a tool when setting project requirements and evaluating the process at different stages. It also allows comparing different alternatives with regard to environmental values.

2. ASSESSMENT METHOD DESCRIPTION

The method for assessing environmental impacts in infra construction is a systematic method with which it is possible to analyse the activities of the project that affect or burden the environment and the resulting environmental stressors and impacts using Decision Analysis and Life Cycle Analysis methods. The indicator method combines emission data obtained from measurements and calculation with specialists' assessments of environmental stressors and the views of the decision makers and specialists on the mutual importance of a project's environmental problems. The assessment method applied in this study is a simplified version of the method developed at SYKE for the analysis of activities that increase the environmental load and environmental stressors in the province of Etelä-Savo (Tenhunen and Seppälä 2000). The acronym of the assessment method is EIMI (assessment method for Environmental IMpacts of Infrastructures).

The assessment method describes the problem of assessing the environmental impact on a value tree hierarchy (Figure 2). The hierarchical structure is based on a classification system that determines the total impact value, which is divided into the environmental impact categories, and further into the groups the environmental stressors associated with the infra construction project according to their cause-effect relationships.

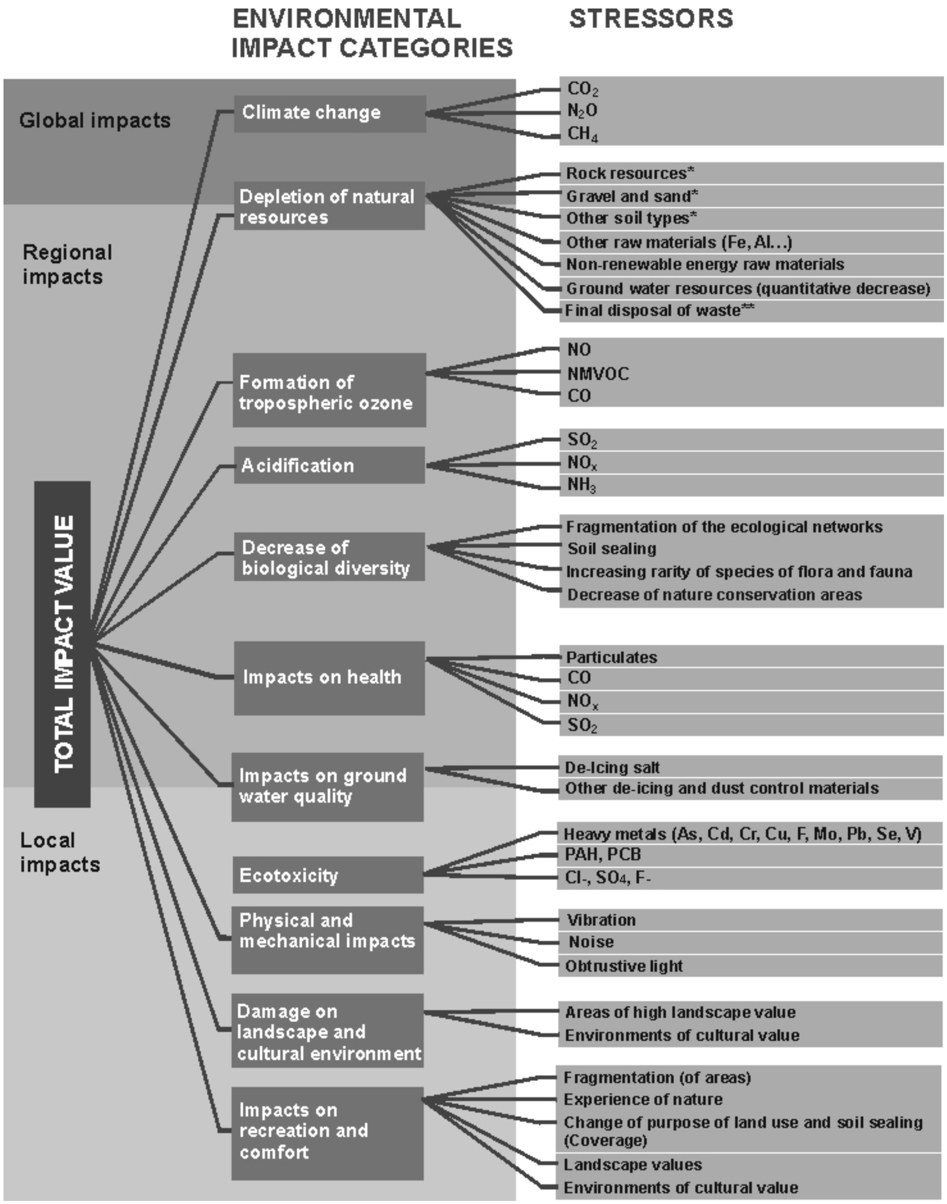

Figure 2. The EIMI assessment method, tree hierarchy.

The environmental impact categories used were chosen on the basis of their perceived importance for infra construction. The choice was based on direct or indirect emissions and other stressors. The method does not take all stressors associated with infra construction into account. If a particular emission and its environmental impact were considered minor, it was not included. However, it is possible to add new environmental impact categories and stressors to the method on a case-by-case basis.

Defining environmental impact categories that would be applicable to an infra construction played a central role in terms of the assessment method's functionality. The categories were to be defined in a manner that would make it possible to assess their mutual importance. According to the theory of Multiobjective Decision Analysis, decision criteria - here, environmental impact categories - should be mutually separate and independent. Furthermore, the categories should, as far as possible, describe the entire range of environmental impacts attributable to the infrastructure.

The stressors associated with each environmental impact category are made equivalents within each category using characterisation factors. For example, different greenhouse gas emissions can be expressed as CO_2 equivalents using Global Warming Potentials (GWPs). The characterisation factors are equivalent factors used in LCA, determined taking current knowledge of the importance of stressors in the given environmental impact category into account.

It is not always possible to specify an exact volume estimate or pinpoint a scientifically justifiable characterisation factor for each stressor. With regard to environmental impact categories associated with these stressors, indicator computation is based on subjective weights assigned by specialists, which will be used instead of characterisation factors. The categories to which the specialists' subjective assessments are applied include physical and mechanical impacts, depletion of natural resources, damage on landscape and cultural environment, decrease of biological diversity, and impacts on recreation and comfort.

Calculating the total impact value with the assessment method is not possible unless each environmental impact category has been assigned a weight. The weighting factors were determined in a workshop from the perspective of minimising the environmental impact of infra constructing. Emissions from road and railway construction projects in Finland as well as emissions for the whole of Finland were used as reference. On the basis of Multiobjective Value Theory, the environmental impact category indicator values must in this case be normalised with normalisation factors calculated according to the emissions resulting from the reference system. This report includes reference calculations from the Finnish road, street and railway construction projects.

3. REFERENCE SYSTEM STUDIES IN INFRA CONSTRUCTION

The research was concerned with producing reference system through a rough assessment of the total annual environmental load of street, road and railway construction in Finland. The goal was to determine the significance of various factors for the environmental load in infra construction, as well as to assess the significance of infra construction with regard to the environmental load on the national level in Finland. The assessment involved street, road and railway construction.

The team first provided estimates of the annual volumes of material resource consumption and transportation and the use of machinery, and then determined the environmental profiles for these factors. In this context an environmental profile refers to a list of harmful emissions and depletion of natural resources per reviewed unit.

A summary of the results is shown in Table 1. The table shows the estimated annual levels of energy and material consumption in road construction, and the environmental load as airborne carbon, sulphur, and nitrogen oxide emissions and particles. Corresponding figures are also given for railway construction and urban street construction.

The project team also roughly estimated the share of the overall environmental load in Finland attributable to street, road and railway construction. For comparison purposes, SYKE collected data on resource consumption and harmful emissions on the national level. The data is from year 2003 (Table 1).

According to this estimation the construction of streets, roads and railways depletes non-renewable energy sources by approximately 11,000 terajoules annually, as well as causes approximately 0.8 million tonnes of carbon dioxide emissions. Street, road and railway construction accounts for approximately 1% (0.6 - 1.1%) of the consumption of non-renewable energy and carbon, sulphur and nitrogen oxide emissions in Finland. This share is significantly smaller than the aggregate share of industry as a whole, however it is on par with some individual industrial sectors.

Table 1. Environmental load resulting from street, road and railway construction as well as environmental load on national level in Finland.

	Units	Road construction	Street construction	Railway construction	Total infra cosntruction	Finland	Proportion of Finland's load (%)
Non-renewable energy	TJ	6 300	4 100	978	11 400	1 130 000	0.1
Non-renewable natural resources	mil. tn	40	6,7	5,1	52 *	92 *	57*
CO_2	mil. tn	0,49	0,32	0,096	0,81	73	1.1
SO_2	tn	300	200	91	590	99 000	0.6
NOx	tn	710	290	277	1 300	219 000	0.6
CH_4	tn	33	7,0	86	126	236 000	0.05
NMVOC	tn	31	15	9,9	56	145 000	0.04
PM10	tn	53	19	3 520	3 600	55 000	0.7

** The figures are not fully comparable since the figure for infra construction also includes materials other than rock and soil (such as fossil resources, which are* *required for the production of fuels and bitumen), while the Finnish figure only includes rock and soil materials.*

The environmental load caused by infra construction results largely to the production of asphalt with regard to parameters other than use of non-renewable natural resources. Road, street and railway construction account for a highly significant share of the consumption of non-renewable natural resources compared with the overall levels in Finland. The figure for infra construction includes all natural resources, including fossil resources. Thus the results are not fully comparable with the figure presented at the level of the whole of Finland since this only includes rock and soil material. Infra construction accounts for approximately 50% of the depletion of the soil and rock in Finland.

4. RESULTS OF THE VALUE ASSIGNING TASK

In the indicator assessment method for infra construction, environmental stressors were divided into environmental impact categories according to their environmental impact (Figure 2). The meth od makes it possible to integrate environmental data into category indicators and, if necessary, into a single figure that describes the entire project. Stressor information is integrated using weighting factors.

The environmental impacts of an infra construction project are largely case-specific. Knowledge of local environmental conditions and the infra plan is a prerequisite for assessment. In this project the goal was to create an assessment method that uses the values assigned to environmental impact categories by specialists and the stressors that lack a characterisation factor. The characterisation factors used in LCA could be applied to some of the chosen stressors, in which case subjective valuation was not necessary.

Assigning weights to the environmental impacts was carried out in workshop, where SMART techniques based on Decision Analysis was adapted. All workshop participants arranged the environmental problems in order of importance, and assigned a weight to each category. The weight given to the least important category was 10.

The infra construction was divided into two parts: the general planning phase, and the construction and maintenance phase. Environmental problems were evaluated separately for both phases. Figures 3 and 4 show the weights that were assigned to each environmental impact at the workshop.

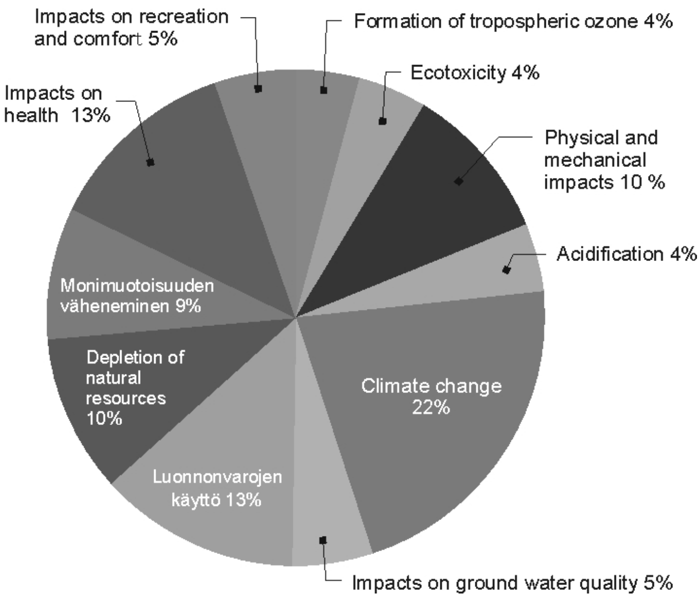

Figure 3. The median weights assigned to different environmental impacts in the general planning phase of the infra project, calculated on the basis of the weights determined by individual respondents.

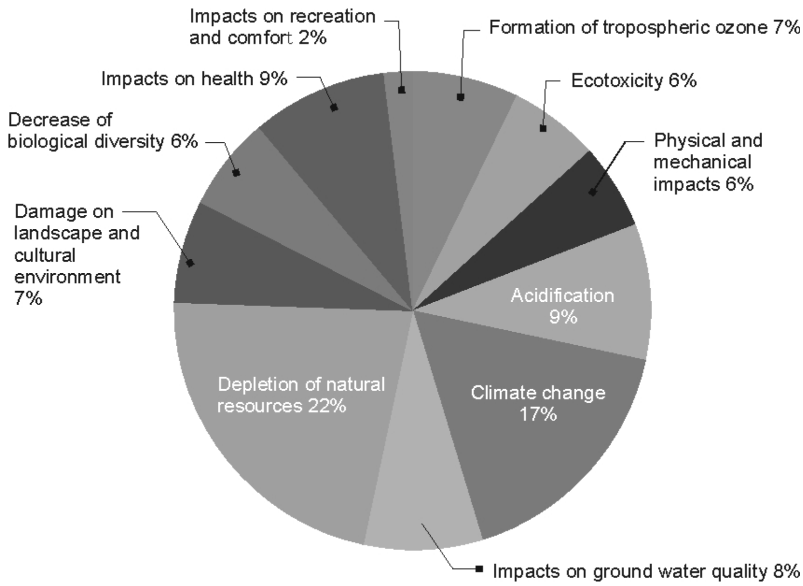

Figure 4. The median weights assigned to different environmental impact in the construction and maintenance phase of the infra project, calculated on the basis of the weights determined by individual respondents.

5. APPLICABILITY OF THE ASSESSMENT METHOD

The environmental indicator assessment method for road construction presented in this report can be applied when comparing alternative solutions or construction methods. The assessment method can be applied at different stages of infra construction. The indicators required at the general planning stage apply to land use and its effects. The indicators required for comparing tenders concern the environmental impact of material and energy flows and natural resource consumption.

The method should also be used when carrying out EIA reviews for infra construction projects. The impact of land use could be systematically assessed using the same land use indicators. When necessary, an approximate model could also be created to assess the volume of material and energy flows.

One potential problem associated with the method is lack of availability of baseline data. In a comparative assessment method it is important that all essential factors are included. Satisfying these criteria may complicate the use of the method, unless a sufficient amount of reliable data is available. To solve this problem the necessary background data on the environmental profiles of various material and energy flows should be available during the design process. The design process should also include computational capacity; for example, the design software used could support environmental impact assessment. When comparing different options, the essential aspect is to be able to pinpoint the differences between them. Thus it is not necessary to include all the data on environmental impacts when using the method for comparison purposes.

The assessment method must be adapted to each project separately. The environmental impact categories and indicator weights should be assessed and set on a case-by-case basis. The scope of the method - the environmental impact categories and indicators - should also be assessed separately for each case.

The assessment method includes all environmental categories deemed important, as well as category-specific stressors. Some stressors currently lack a suitable indicator that describes or measures its environmental load. These categories or stressors lacking a distinct indicator include obtrustive light or noise.

The total impact value calculated with the method can be applied in various ways to steer procurement. An application procedure with full instructions does not exist for the time being. The ”Pilot projects for life cycle studies in road maintenance” project (Korkiala-Tanttu et al. 2005) created two different methods for considering environmental impact in procurement. In the first pilot project (Mt307), the environmental impacts calculated with the Meli software were assigned values in the range of ± 10% at the tender comparison stage. The environmental impact at the site was calculated in proportion to the environmental impact of the reference site. Another pilot project (Vt9 - Lieto) applied the fixed price design and build contract, i.e. the purchase price was fixed and contractors were evaluated on the basis of the life cycle quality they offered. The comparison was based on a multivariate analysis and the environmental impact was assigned a weight of 10%.

The current life cycle assessment method includes a large amount of background data (such as the environmental profiles of different materials), which is why its use requires a suitable calculation tool. It also necessitates an application procedure with full instructions, or a standardised procedure for a mutual assessment of costs, functionality and environmental impact.

6. CONCLUSIONS

The environmental impact assessment method for infra construction can be used to compare both alternative design solutions and construction techniques. It can probably be applied when comparing road geometry (both horizontal and vertical) alternatives at the planning stage and tenders in the construction and maintenance stage. The method can also be adapted for use in EIA reviews for infra construction projects. It is likely that rather than an individual construction project, the method could be applied to road construction at the land-use planning phase to compare various land use plan options. The goal was to create an indicator assessment method that includes all environmental categories deemed important, as well as the category-specific stressors.

There are some factors that are restricting method application. They are: availability of necessary baseline data, all of the essential factors should be included when comparing alternatives, the presented weights are rough estimates; the environmental impact category and indicator weights applied should be assessed and set on a case-by-case basis, the scope of the method - the environmental impact categories and indicators included - should also be assessed separately in each case, some stressors lack an indicator or a method of measurement, for which reason they must be excluded from the review at this stage and characterisation or normalisation factors do not exist for each stressor.

The assessment method is a systematic method for assessing environmental impacts. While some information is always lost when the method is applied, it is an efficient tool for comparing different options: it reveals their mutual order of superiority. The accuracy of the result depends on how successfully the method has been applied. Furthermore, it should always be remembered that the method includes subjective weights, which are transparent. So they can be changed from case-to-case basis.

The assessment method has been developed as a decision-making tool - not to describe the absolute total impact value. The presented assessment method contains factors and values that change often as changes occur in society or the environment, or which may not yet be fully known. Thus the method requires continuous improvement and augmenting.

7. FURTHER RESEARCH

The developed assessment method opens opportunities for aiming at ecoefficiency in public procurement. The first-version method has its defects and limitations. Applying the model also requires the development of various calculation tools for assessing the total impact value, as well as a method for comparing different factors in procurement. Further research should focus on the three themes mentioned above.

The assessment method, the indicators included and the calculation tools required for the application of the method should be further specified and developed. In the first phase it is advisable to focus the development on factors that are deemed to have the heaviest environmental impact. This development includes various land use and ecology-related factors in particular. The development should be continued from a maximally wide perspective, involving expertise from all areas concerned with the environmental impacts of construction, construction design and implementation.

Using the method requires sufficient data on the sites to be reviewed, and their structures. The required background data includes mass and logistics information, which is available from design software, and the environmental profiles of different materials, on the basis of which it is possible to calculate the environmental impact of each option reviewed. The tools required for the collection and processing of this data can be divided into two categories: calculation tools for comparing construction or maintenance activities, and an indicator-based assessment method for the land-use planning phase and for assessment on the general and road planning level.

If we are to take ecoefficiency into account in procurement, we must have procedures with full instructions or standardised procedures for including environmental impact data in the decision making. The procedures - or at least the weights assigned to them - will probably be sector and contract-specific while complying with a standardised framework. Thus development should be carried out as industrial cooperation under the INFRA2010 program for example.

8. REFERENCES

Korkiala-Tanttu L., Törnqvist J., Eskola P., Pienimäki M., Spoof H. ja Mroueh U.-M. (2005) Elinkaaritarkastelut tienpidon hankintoihin; kokemuksia kahdesta pilot-kohteesta, Tiehallinnon selvityksiä 13/2005, Helsinki, s. 43 + liitt. http://alk.tiehallinto.fi/julkaisut/pdf/3200925-velinkaaritarkasthank.pdf

Lehmus E., Eskola P., Häkkinen t., Korkiala-Tanttu L., Mroueh U.-M., ja Tu-hola M., (2002) Infra-alan elinkaaritarkastelut, esiselvitys, VTT Rakennus- ja yhdys-kuntatekniikka sisäinen raportti, RTE50 - IR - 22/2002, Helsinki, s. 49. + liitt. 8 s. Espoo,
http://websrv2.tekes.fi/opencms/opencms/OhjelmaPortaali/Kaynnissa/Infra/fi/Dokumenttiarkisto/Viestinta_ja_aktivointi/Julkaisut/Elinkaaritarkastelut.doc

Tenhunen J. & Seppälä J. (2000), Alueellinen ympäristöanalyysi. Esimerkkinä Etelä-Savo. Suomen ympäristö 383. Helsinki : Suomen ympäristökeskus, - 110 s