Implementation of life cycle thinking in planning and procurement at the Swedish Transport Administration

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ABSTRACT: According to transport policy objectives, limiting the energy use and climate impact of the transport system, including infrastructure, is an important task for the Swedish Transport Administration (STA). Choices that affect climate performance of transport infrastructure are made at different stages in the planning process. The STA has developed the Klimatkalkyl climate calculation model for an efficient, consistent life cycle calculation of infrastructure greenhouse gas emissions and energy use. As a result of the model's implementation in planning and procurement, a life cycle perspective is now being used on a regular basis for environmental procurement claims, decision support and monitoring purposes.

1 INTRODUCTION

According to transport policy objectives, limiting the energy use and climate impact of the transport system is an important task for the Swedish Transport Administration (STA). This task includes limiting the climate impact of both traffic and infrastructure.

The transport system affects the climate through emissions from traffic as well as emissions from the construction, operation and maintenance of infrastructure. The STA is responsible for long-term planning for the domestic transport systems of all types of traffic, as well as the construction, operation and maintenance of public roads and railways. The Government's infrastructure bills of 2008 and 2012 (Swedish Government, 2008) emphasize that decision support should take into account the climate impact of infrastructure from a life cycle perspective. There is also the vision of Sweden having zero net emissions of greenhouse gases by 2050 (Swedish Government, 2014).

A life cycle perspective is needed to include the indirect emissions that occur as a result of producing the materials and fuel used in construction, as these emissions may be significant for the transport infrastructure system (Jonsson, 2007; Chester and Horvath, 2009). As described in the *Handbook on Life Cycle Assessment* by Guinée et al. (2002) and discussed by Harvey et al. (2016), life cycle assessments (LCAs) can be categorized according to level of complexity, depending on the objective. These assessments may be benchmarking studies, studies with only a few impact indicators or selected life cycle stages, or full-scale LCA studies that include a life cycle impact assessment for a larger set of impact and resource indicators. LCAs can be applied on both a network level and a project level. Within the literature a wide range of LCAs for transport infrastructure have been published, differing in scope, system boundaries and complexity. There are studies that concern the entire transport system (Schlaupitz, 2008; Jonsson 2007), as well as studies that concern single projects or components of a project (i.e. Muench, 2010; Santero et al., 2010).

As suggested by Butt et al. (2015), in order to make appropriate methodological choices for an LCA, one should consider at which stage during the planning process the LCA results will be used. Choices made for early planning stages will influence energy use and climate impact during construction and maintenance. From an energy and climate perspective, there is a considerable difference between construction inside a tunnel, in a cutting, on high embankments and at ground level. The volume of earth movement and material use is affected by the choice of location and design. However, choices made during later planning stages will also affect energy use and climate impact. Specifically, these include choice of design, materials and suppliers. Miliutenko et al. (2014) have investigated the decision stages of road infrastructure planning in Sweden, Norway, Denmark and the Netherlands and suggested three main decision stages when a life cycle perspective may be applied. These are the choice of transport modality at the national level, choice of road corridor and construction type in a given project, and choice of specific construction design.

In order to achieve the goal of reduced emissions from transport infrastructure, there are several requirements to be considered: emissions need to be consistently attributed and reported; effective reduction measures need to be identified; and there need to be incentives that promote the implementation of those measures on both network and project levels, in both early and later stages. Furthermore, in order to achieve this in a way that is consistent and guarantees that all projects are evaluated on the same basis, the system boundaries, background data and other methodological choices need to be transparent and clearly defined. For this purpose the STA has developed the Klimatkalkyl climate calculation LCA model (STA, 2016a). This model has been implemented in the regular planning process and is also being used for formulating requirements in the procurement of contractors and consultants. The aim of this paper is to describe the model and its contribution to the implementation of a life cycle perspective on greenhouse gas emissions within the planning and procurement processes of Swedish transport infrastructure.

2 THE KLIMATKALKYL CLIMATE CALCULATION MODEL

2.1 *Model development*

The Klimatkalkyl climate calculation model has been developed to enable the calculation of potential climate impacts in terms of the global warming potential (GWP) of greenhouse gas emissions and to account for energy use. The model covers construction as well as operation and maintenance of investments for roads and railways. In addition, the model has been developed for use both in the early planning stages when there is little project specific information available and in the later stages of a project. The model is designed so that climate calculations can be applied continuously to a certain project throughout the planning process. As the project proceeds, the results will gradually become more precise. The model is also designed to be user-friendly. No information input is required beyond what is available through the investment cost assessments. Furthermore, the model has been designed with the aim that it should apply to individual investments as well as to elements of investments, and that it should be possible to aggregate the results. Results for an entire transport plan can thus be obtained by adding together the individual results of the different investments within the plan.

The model has been developed by the environmental consultancy company WSP at the request of, and in consultation with, the STA. The first version of the model, Klimatkalkyl version 1.0, was developed in connection with the STA's preparations for its proposed 2013 National Transport Plan. This version of the model was used to estimate the greenhouse gas emissions derived from the construction of the investment elements specified in the plan (STA, 2015). The model has been updated annually since then; the latest version – version 4.0 – became operational in April 2016 (STA, 2016a).

2.2 *Model description*

The Klimatkalkyl model applies the basic principles of LCA in accordance with ISO 14044 (ISO, 2006a; 2006b). The model calculates energy use (primary energy) and greenhouse gas emissions (global warming potential (GWP) quantified as emissions of CO_2 eq.) for an object or a measure by multiplying resource use by emission factors. The emission factors constitute background, or generic, LCA data that should be conservative average values representative for today's most common techniques. The LCA data should also be geographically representative. The model provides the option for constructors or designers to change the LCA data. The STA accepts LCA data based on published environmental product declarations (EPDs) in accordance with the standard for EPDs published as EN 15804 by the European Committee for Standardization under Technical Committee 350 (CEN, 2013). The emission factors include the energy use in – and emissions from – raw material extraction and the processing and transportation of energy resources and materials, as well as from the use (combustion) of the energy resources. The emission factors are reviewed and updated on a regular basis.

The model is a modular framework in which type measures contain a predefined set of components. Each component contains a predefined set of resources and each resource is linked to the generic LCA data provided as default. The model contains default resource templates for the expected use of resources in different type measures or components. Resource templates are based on earlier projects. Users of the model can choose either to use the default values for resource use and the generic LCA data, or to apply project-specific resource use and resource-specific LCA data. In the early planning stages the resource use and specific materials and suppliers are not yet known, and at these stages the default values are necessary, but as the level of detail increases toward the later planning stages, data that is more project specific can replace the default values. Resource templates also exist for the operation and maintenance of the most important type measures. Today, however, opportunities for using project-specific data for operation and maintenance are limited due to verification problems: while resource use and generic LCA data can be verified through project information and product-specific EPDs, future resource needs for operation and maintenance cannot be validated.

2.3 *System boundaries*

The Klimatkalkyl model considers the energy use (primary energy) and potential climate impact (emissions of CO_2 equivalents) of road and railway infrastructure. Construction, operation and maintenance are the life cycle stages included. An end-of-life stage for the construction as a whole is not included, as transport infrastructure is rarely demolished. Instead, the function of the infrastructure system is assumed to be kept constant by the ongoing replacement of components as they reach the end of their reference service life. The emissions from construction of each component, including material and processes, is divided by its reference service life and summed up as a total. This means that environmental impact is distributed forward in time throughout each components service life although the emissions occur during the limited time period of construction. Demolishing and waste management of each component is not included by default in the calculations, as it commonly contributes very little to the total emissions. However, demolition can be added manually by the user of the model. The components' reference service life are defined on the basis of previous experience.

The energy use and emissions of traffic are not considered in Klimatkalkyl; these are currently analyzed in other models. This is, however, one development potential of the model. As decisions regarding infrastructure influence future traffic, both on a project level (e.g. through roughness and rolling resistance) and on a network level (e.g. through the lengths of transport), there will be a future need to define the interface between Klimatkalkyl and existing models for the calculation of traffic emissions and energy use.

The model calculates emissions and energy use on the basis of current technology and material choices, and any marginal effects are not considered. This is in contrast with many road traffic analyses, which do consider future technology developments. However, Klimatkalkyl does allow for such aspects to be added manually for individual project calculations.

All types of transport generated within the projects that are specified as cost items in the original cost estimate of the project are included in the model. This means, for instance, that earth and rock moving within the project is included. Emissions from transport during raw material extraction and processing are included in the emission factors. However, transportation from production site to construction site is not included. These types of transport are generally assumed to represent a minor contribution to energy use and greenhouse gas emissions (Bothnia Line, 2010), although they may, in some cases, be significant. However, the model is being developed on an ongoing basis and the aim is to include resource templates for all types of transport.

Items included as ongoing operation and maintenance are winter road maintenance, pavement maintenance and tunnel operation (lighting, ventilation and pumping water). The model provides the opportunity to add lighting points separately. Winter road maintenance includes the use of salt and sand, as well as the energy used for spreading these and for snow clearing. Operation and maintenance of railways includes point machines, rail grinding, switch heating, heat and power to station buildings, power to signal systems, and tunnel operation (lighting, electronics, and frost avoidance for fire protection water).

The points mentioned above have been identified as significant contributors to energy use and climate impact, based on previous experience of the STA, certified environmental product declarations (EPDs) and the STA's ongoing development within the field of life cycle cost assessments. On the basis of the above sources, a number of measures are assumed to be minor contributors to energy use and climate impact and these are not included in the model. Such operational measures include railway snow clearance, weeding, dust binding, inspection, sweeping, clearance of obstacles etc.

3 LIFE CYCLE THINKING IN PLANNING

3.1 *Implementation of Klimatkalkyl in the planning process*

Since 2015, the STA has regularly used the Klimatkalkyl climate calculation model to implement life cycle thinking for all new investments of greater than SEK 50 million and for projects included in Sweden's National Transport Plan. Climate calculations are performed from the early planning stage, when different solutions are compared on a network level, and throughout the planning process for the specific solution chosen, until the construction is finished and a climate declaration is delivered. The results are included in the overall impact assessment published for each project at certain predefined steps within the planning process, as prescribed by the guidelines of the STA (STA, 2015). At each of these steps, the cost calculations are revised and the climate calculation is updated on the basis of the cost calculations. Hence, climate calculations are systematically being performed and up-to-date, available as decision support throughout the planning process with a minimum of effort.

The climate calculations are used for decision support (i.e. what to build and how to build it in order to optimize climate performance) and for monitoring. Klimatkalkyl has been successfully used in major projects such as the Stockholm Bypass Project and the East Link Project – for example, to compare alternatives in environmental impact assessments (EIAs) and identify emission hotspots. In the East Link Project, four different road corridors were compared, in terms of greenhouse gas emissions from the infrastructure. The one alternative with the most tunnels turned out to be the worst one due to the large amounts of concrete needed. In the Stockholm Bypass Project, concrete and steel were identified as the materials that contributed most to the greenhouse gas emissions. The project is now looking for steel suppliers with lower carbon footprint. Although the Klimatkalkyl climate calculation model is the only model prescribed by the official guidelines, it may also be combined with other, more detailed tools for the further identification of hot spots and resource-efficient design.

4 LIFE CYCLE THINKING IN PROCUREMENT

4.1 *Implementation of Klimatkalkyl in procurement*

In order to achieve the goal of the improved climate performance of the transport infrastructure, it is not enough to only implement life cycle thinking for decision support within the planning process. External actors such as contractors and material suppliers also need incentives for reducing greenhouse gas emissions within their processes. Therefore, the STA is now implementing climate requirements, based on life cycle climate calculations, in procurement (STA, 2016b).

Since February 2016, all projects greater than SEK 50 million that are planned to be finished in 2020 or later will be covered by the requirements. The requirements focus on achievements in terms of total decreased emissions rather than prescribing a specific technical solution, in order to achieve the most effective solutions and to stimulate innovations. Tenders are still being evaluated on the basis of price, but the contracts which have been generated include a requirement to reduce greenhouse gas emissions as compared against a predefined baseline. Consultants contracted by the STA at the planning stage or design stage are required to present measures for decreasing greenhouse gas emissions. Turnkey and construction contracts have quantitative requirements for reduced greenhouse gas emissions. Contractors' initial base-line for greenhouse gas emissions is set by the STA according to the Klimatkalkyl model. Compliance with the quantitative requirements is verified by a climate declaration within the same model. If the requested reduction in emissions is achieved, or even exceeded, contractors may be awarded a bonus. If the reduction is not achieved, other bonuses may also be suspended. By using the Klimatkalkyl model for all projects, for base-line setting and for verification by the final climate declaration, an equal process with similar system boundaries is ensured.

4.2 *Reduced greenhouse gas emissions*

The process of implementing the climate requirements and setting the level of reductions was carried out in close cooperation with consultants and contractors. During the first five-year period, on average a reduction of greenhouse gas emissions of 15% is asked for, as compared with the predefined baseline. The exact level of reduction to be required varies depending on the type of project. Reduced greenhouse gas emissions can be achieved either by changing the type or amount of material and fuel used, or by using material and fuel suppliers with a better climate performance in their production processes (e.g. products with a higher proportion of recycled material). In the former case, the default templates for resource use in the Klimatkalkyl model are replaced by project-specific values for the different predefined components, or new components are added if necessary. In the latter case, the generic LCA data provided in the model are replaced by resource-specific LCA data, verified through EPDs.

5 CONCLUDING DISCUSSION

5.1 *Current achievements*

In recent years, the Klimatkalkyl model has been used to produce life cycle perspective climate calculations for hundreds of projects. In 2013 the model was used to evaluate the 2014-2025 transport plan. The evaluation revealed that construction of the planned projects would result in emissions of 3.8 million tons of CO_2 eq (STA, 2014) (the model at that time included only the life cycle stages of raw material extraction, transport and processing, and construction). Since then, use of the model has been incorporated into regular practice for decision support, for identifying improvement measures, for monitoring purposes, and for defining initial baselines and verifying achievements within procurement. All larger projects are now accompanied by a climate calculation by which their climate performance and the effect of their improvement measures can be followed. Although the climate requirements are still a very new element of the procurement process, they are already having an effect in terms of the EPDs being generated. The EPDs are required for verifying the climate performance of contractors' solutions. The requirements are expected to stimulate the development of materials and fuels with better climate performance. There is an ongoing project to evaluate the responses to the procurement requirements among the actors concerned and to evaluate if the desired developments will be achieved.

5.2 *Uncertainties*

Uncertainties in the results from the Klimatkalkyl climate calculation model mainly derive from either the generic LCA data used, the default templates for resource use, or the project-specific data inserted by the user.

Regarding the generic LCA data, these values are based on published and reviewed sources (preferably EPDs) and are regularly revised and updated. As the number of published EPD is growing, the possibilities for improving the default values increases. The LCA data for steel, concrete, bitumen and diesel are of particularly great importance to the overall results.

Regarding the default templates for resource use, the possibilities for successively improvments of these templates will increase as climate declarations are performed, providing results regarding the resource use in completed projects. However, the variation between projects may largely depend on environmental aspects such as geological conditions, or specific design choices. Therefore the user is encouraged to routinely check the representativeness of the default values used and modify these when necessary.

The uncertainties that derive from the insertion of data by users are judged to be the most important. In the early planning stages in particular, knowledge of project components may be poor. Thus, when interpreting the results from the model, it is important to bear in mind that the results can never be more precise than the data used.

5.3 *Further work*

The Klimatkalkyl climate calculation model is constantly being improved to better support life cycle thinking in both planning and procurement. One example of needed improvement is the expansion of system boundaries so as to better address use and maintenance activities, the transport of materials from production to site, and demolition activities. The model may also be developed to include a broader range of environmental impact categories. A development of this kind is needed in order to address the high level of complexity of full LCA studies that can deliver a life cycle impact assessment for a large set of impact indicators (Harvey et al., 2016).

For use and maintenance activities, it is currently not possible for a user of the model to replace default templates with project-specific information. However, if future use and maintenance cannot be modified, there will be little incentive to design a construction with less intensive maintenance. Therefore, the development of such opportunities will be an important measure to avoid sub-optimization. The methodological challenge is to find a consistent, practical process for verifying project-specific data in future use and maintenance.

Furthermore, it is necessary to establish useful interfaces with other models – e.g. models which describe the environmental impact of traffic. Traffic emissions need to be considered when the model is to be used in the early planning stages – e.g. as decision support in the choice of road corridor, which today is a manual process involving the comparison of traffic calculations. With further development of the model, this process may become more effective and consistent. There is also a need to develop and improve the interface with more detail-oriented models that focus on subsystems, e.g. pavement design, so that the information obtained through the use of these models can be effectively utilized.

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