STATE OF THE ART OF LCA TOOLS AND METHODS FOR INFRASTRUCTURE, FOR FINLAND, SWEDEN AND NORWAY
PROJECT
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SUMMARY

There are several benefits for common way of working with LCA. One is to get comparable results. Other benefits are to help visualize environmental impact through all processes from planning to designing and construction further to operation and maintenance and follow-up.

Possible applications of the LCA tools are:
- Environmental budget to be used by the NRA internally
- Tender procedures (requirement or award criterion)
- Accounting for environment after/during construction

This report describes the most common tools used by the transport administrations in Finland, Norway and Sweden. The objective is to find similarities within the tools to find a common way of working with LCA in infrastructure projects and to learn from each other.

Below, the tools from each country is briefly described.

FINNISH TOOLS

There are nearly 20 years of experience of LCA calculations of road construction in Finland. Several tools have been used for LCA but it is not mandatory to make LCA calculations of infrastructure projects in Finland. Development of a LCA tools for infrastructure projects in Finland started with MELI (earthworks, pavements and soil improvement) at 1999 by VTT. Meli tool uses a database containing the environmental burdens of the most significant construction materials and unit operations for road infrastructure. LCA calculations during public procurement have been piloted with Meli at procurement of two highway design-build-contracts. Fore-Scope, Fore-Hola and Fore-Rola are tools for calculation of construction costs of roads, railways and streets and other infra in Finland. Fore-Scope is used at city planning level, Fore-Hola is used at planning level and Fore-Rola is used at design level. LCA calculations with Fore are done based on calculations construction costs - amounts are evaluated by planner/designer. Fore uses average values for construction costs, quantities and emission coefficients. One Click LCA is an automated tool for LCA and LCC assessment for construction industry with local data. The tool uses BIM for calculations and also other kind of input data can be given. It is currently being updated with infrastructure parts.

NORWEGIAN TOOLS

One LCA tool, and two LCA methodologies for road and rail infrastructures are currently available in Norway (to various degrees). The tool, VegLCA, is currently being tested for use. One of the methodologies, the Climate Module in EFFEKT, is in use. The second methodology is currently being developed and structured, and is partly in use at its current version. EFFEKT and VegLCA handles road infrastructure and can be applied at an early planning phase and in the design and contract phase respectively. The Method for generic road and rail elements can be implemented in all planning stages where the geometry and class of relevant infrastructure constructions are known, but if data on amounts of materials and energy use is available, VegLCA is more suitable. The method does not cover all relevant road and rail constructions and elements in its current version. Together, these tool/methods can potentially cover all phases of road infrastructure planning in Norway.
SWEDISH TOOLS

STA uses three different tools to calculate both cost and greenhouse gas emissions. The most used tool is Klimatkalkyl, which can be used in all stages of an infrastructure project. The results is given in CO$_2$e and primary energy use.

Geokalkyl is a tool for evaluation of infrastructure alignment, in early stages of the project. It is very visual since it uses GIS to present the CO$_2$e results in a map. It focuses on geotechnical reinforcement measures and obtaining mass balance for each alignment, analyses different structural parts, like bridges, tunnels etc or conflicting interests. Geokalkyl calculates construction cost, energy- and CO$_2$e consumption.

The tool EKA calculates greenhouse gas emission and the primary energy used in asphalt manufacturing – from input materials to finished coating of a road. Production and laying of the road is included in the LCA calculations. Calculations in EKA serve another LCA tool, “Klimatkalkyl”, with data regarding finishing coating of roads.

The need for common guidelines appeared to be bigger than the need for common tools. Developing a common tool is not key, as the tools as they are today give the results needed. It is more important to work on a good common basis for the tools (standards and framework) in a guideline. NordLCA should therefore not focus on translating and adapting tools. However, some of the existing tools would be a valuable addition in other countries. This applies mainly EKA, Geokalkyl and EPD generators. NordLCA should facilitate translating and adaptation of such tools on request.

There is a wish for more meetings like the workshop at 14.09. Continued work on common guidelines in the same grouping that produced this report in the form of some planned workshops during the Northern LCA project. The proposal is that NPRA, STA and FTA are convening and calling into consultants who attend Workshops when needed and doing work / “homework” between workshops. Other types of experts should also be involved: BIM, LCC, contractors, plan phase experts, etc.
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1. SUMMARY OF ALL TOOLS
1. INTRODUCTION

Reduction of climate impact is highly prioritized and in order to support good decisions and choices throughout the process, good methods and tools are necessary. Three Nordic National Road Administrations; Finnish Transport Agency, Norwegian Public Roads Administration and Swedish Transport Administration, joined forces in order to further develop their LCA tools for assessing the climate impact from the construction of infrastructure.

There are several benefits for common way of working with LCA. One is to get comparable results. Other benefits are to help visualize environmental impact through all processes from planning to designing and construction further to operation and maintenance and follow-up.

Possible applications of the LCA tools are:
- Environmental budget to be used by the NRA internally
- Tender procedures (requirement or award criterion)
- Accounting for environment after/during construction

The Nordic countries have largely similar conditions in terms of road construction, raw materials and machinery. The purpose of this report is to describe the existing tools and describe the strengths and scope of the relevant applications.

In order to get an understanding and a common starting point, this document was produced describing the most commonly used methods and programs in Finland, Norway and Sweden. For Finland the programs Fore, Meli-HEL and One Click LCA are included. For Norway the programs EFFEKT and VegLCA are included. For Sweden the programs Klimatkalkyl, EKA and Geokalkyl are included.

2. STATE-OF-THE-ART OF FINNISH, NORWEGIAN AND SWEDISH LCA TOOLS

As a baseline, the most common tools used by the transport administrations have been described in a general way. Specific questions have been answered and are presented in a table found in Attachment 1, where all tools are represented.

2.1 FINNISH TOOLS

2.1.1 GENERAL

There are nearly 20 years of experience of LCA–calculations of road construction in Finland. Several tools have been used for LCA. Development of MELI tool (earthworks, pavements and soil improvement) started at 1999 at VTT. MELI was tested in rewarding design–build–contracts of roads between 2003–2005. The results of the tests were assessed: transportation distance of aggregates was the most decisive factor in bidding. Shortest transportation distance of aggregates led to least impacts on environment and also lowest costs and thus lowest bidding
price. In the tested contracts LCA–calculations had no real influence on rewarding the contracts and after that the interests to use LCA–calculations in contracts decreased and a more practical approach for LCA was developed: At the moment in Finland LCA is not routinely used as a tool in contracts. But instead LCA is used to point out the environmental criteria in special cases and the main idea has been that usually the following general factors lead to satisfactory eco–efficiency:

- environmental legislation, taxes of fuel and energy (these means lead the contractors to make better choices – for example to choose more eco–efficient fuel)
- contractors goal to minimize costs (minimizing costs means in practice minimizing transports and minimizing material use which also means less emissions)
- FTA guidelines take eco–efficiency into account
- In addition to the general principles, project specific requirements are needed for
  o Environmental management systems of contractors (as a (minimum) technical requirement)
  o Recycling of demolition materials
  o Machinery
  o Use of recycled materials (e.g. waste tax can lead to very long transports and thus increase environmental impacts)

FTA’s current focus is on reducing greenhouse gases (GHG). The GHG–reduction goals are very challenging and hard work is needed to succeed. This means that all existing means are to be put to use and a wise strategy is needed to move forward and a new perspective also to LCA calculations is needed and the above described general principles needs to be re–assessed – it might be that “satisfactory results” is not enough anymore.

LCA–calculation of road, street and rail construction projects are not routinely done in Finland at the moment although some piloting has been done. During 2014–2016 greenhouse gases calculations of the Kivikontie interchange were done at design phase and after construction (tools: FORE, Meli–HEL, One–Click–LCA). Calculation results differ between the LCA–tools. This is due to different ways of calculating materials emissions, different breakdown structure of working phases and machine work and different methods of evaluating impacts. This is illustrated in Figure 1 below. The calculations of Kivikontie interchange have been reported (in Finnish, not public)\(^1\).

\(^1\) Kivikontien eritasoliittymän katuhanke – CO\(_2\)–päästölaskenta ja laskentamenetelmien arviointi, 2017
Integrating LCA with BIM of infrastructure is, at the moment, not possible since the current infrastructure BIM–standards (in Finland InfraModel3) don’t include construction quantities. There is an ongoing research/piloting about integrating BIM with calculation of quantities and costs in Kira–Digi–research program. Linking LCA with BIM has been tested with Fore–tools. The main findings from the project were that the current tools, that are used for design and planning of infrastructure, don’t yet enable linking BIM with LCA calculations. Also, standard nomenclature and standard data transfer models need to be developed further.

A common finding when evaluating all Finnish tools where that they would benefit if there were more LCA–calculations of road, street and rail projects since the development issues only pop up when the tools are actually used.

2.1.2 FORE

Fore is a commercial set of tools for calculation of building costs. Quantities are measured from the plan/design based on Finnish Infra2015 nomenclature. The tools are owned and developed by Rapal Ltd.

Fore–Scope, Fore–Hola and Fore–Rola are tools for calculation of construction costs and quantities of roads, railways and streets and other infrastructure in Finland. Fore–Scope is used at city planning level, Fore–Hola is used at planning level and Fore–Rola is used at design level. All Fore tools are based on the same hierarchical structure and thus the calculations from earlier project phases can be easily used as a basis for the next phase.

Fore–Rola is the most commonly used tool for calculation of construction costs and quantities of infrastructure works and the tool is used almost in every road planning and design project in Finland. Fore is mainly used in Finland but there are some experiences from other countries. Fore calculates the costs and quantities based on Finnish national Infra2015 nomenclature for
the entire infrastructure sector, Fore’s standard costs database and Fore’s modelled breakdown structure of building elements and building actions.

Fore uses average costs quantities and emission coefficients. Product specific costs, quantities and emission coefficients cannot be used. For calculation of energy consumption and emissions of vehicles Finnish national Lipasto-database (maintained by VTT) has been used as a basis. The emission factors that have been used for the calculations of Kivikontie interchange have been reported.

LCA–calculation with Fore has been tested in some pilot projects (infra: roads, railways and streets, outcome: CO₂ and CO₂e). At the moment Fore doesn’t have a ready to use LCA–calculation tool. The LCA–calculations are done based on building costs evaluated with Fore–Rola (or other Fore tools). The actual LCA–calculation is done by experts at Rapal. The process of LCA calculation is: measuring quantities from plan/design based on Infra2015 nomenclature, calculating costs, calculating use of materials and workloads using Fore’s modelled break–down structure of infrastructure construction works, choosing emission factors and calculating emissions. The project breakdown structure and process of calculating emissions with Fore tool is presented in the Figure 2 below.

![Figure 2. Project breakdown structure and process of calculating emissions with the Fore tool.](image)

The use of Fore for LCA–calculations of infrastructure projects has been reported in following publications:

- Herva et.al. CO2–päästö– ja kustannusohjaus mallipohjaisesti. Liikenneviraston tutkimuksia ja selvityksiä 47/2015. [web link]

Development of Fore

Fore is at the moment not a tool ready to use for LCA calculations since the LCA–calculation part is always done by Rapal Ltd. The tool has so far been used only for CO2 and CO2–eqv calculations. If other emissions categories would be calculated, there would be needed some development work.

2.1.3 MELI

The development of Meli tool started at the end of 1990’s. A two–stage study; ”Life cycle analysis of road construction and earthworks”, was part of a more extensive Finnish research project. In the first part of the study a life–cycle impact assessment method was developed and in the second part of the study the method was tested in pilot projects of road construction. During the project a database containing the environmental burdens of the most significant construction materials and unit operations was constructed. The development is very thoroughly described in the research report2 published by Finnish Road Administration.

Some parts of the Meli–database have been updated after the first developments. Meli–HEL tool has been developed for the City of Helsinki and the tool is used to assess LCA of soil reinforcement methods. Web–based Meli2017 tool has been developed for planners and designers based on Meli. Below, Figure 3 shows how the results are presented in the tool.

![Figure 3. Results from Meli calculations.](image)

The use of Meli for LCA–calculations of infrastructure projects has been reported in following publications:

2 [web link]

**Development of Meli**

Meli is an excel–based program and it can only be used for calculations by VTT or LCA–experts. There are plans to have a web–based version of Meli available quite soon for planners and designers. This version of Meli will be linked with a program licence cost for the user. The user–interface of Meli isn’t very user–friendly. Meli would benefit if there were several type–structures for calculations – at the moment there’s only one type structure of a road section included.

2.1.4 **ONE CLICK LCA**

One Click LCA is a tool owned and developed by Bionova Ltd. The tool is used for LCA and LCC assessment for construction industry with local data and certifications from several rating systems (like BREEAM, LEED and DGNB). One Click LCA uses BIM for calculations and also other kind of input data can be given (MS Excel and IFC). There is a plug–in for input data that works with structural and architectural models of buildings. If BIM for infrastructure would already include quantities and specific information about materials BIM for infrastructure could also be used in calculations. Figure 4 shows the input page where amounts of construction product are reported.

The database and emission factors that are used for calculations with One Click LCA have been collected by Bionova Ltd from EPD’s from materials producers and also from other data sources. The quality of collected emission factor data is always verified through Bionova Ltd’s own processes. The data collection and verification process of Bionova Ltd has been certified by a notified body and the process is regularly inspected. Bionova Ltd has several databases that are adjusted to national uses. The tool also allows the use of the Ecoinvent database.
Figure 4. Input page of the One Click LCA.

Using One Click LCA to LCA calculations of infrastructure projects has been reported in following publications:


Development of One Click LCA

One Click LCA has been mainly used for LCA–calculations of buildings. The program would benefit from specific development of LCA–calculations of road, street and rail projects. For example regarding paving contracts, the reports should include transportation lengths of aggregate material, proportion of recycled asphalt, bitumen percentage, the quality of fuel used, production temperature and transportation length of asphalt to the laying site (the development issue regarding reporting is brought up in FTA 43/2017 and it is stated in the research report that it concerns also EKA and British aSpect).
2.2 NORWEGIAN TOOLS

2.2.1 CLIMATE MODULE IN EFFEKT

EFFEKT is a tool for assessing the socioeconomic cost–benefit for road projects. EFFEKT is developed by the Norwegian Public Road Administration (NPRA), and is mandatory to be used in impact assessment at an early planning stage of all road infrastructure projects. EFFEKT is used particularly to compare various road alignments. The EFFEKT Climate module was implemented in 2011, and revised in 2014 and 2016. EFFEKT (and hence the Climate Module) covers open road sections, bridges, tunnels, ferries, pedestrian/bicycle lanes and sidewalks, earthworks, blasting, mass transport, railings and drainage systems. Activities included in operation and maintenance are: resurfacing, operation of ferries, repainting of ferries, lighting, tunnel ventilation and pumping in subsea tunnels. Road traffic is not explicitly included in the Climate Module, as this was already implemented in EFFEKT before 2011. Estimates of material consumption are based on generic road elements per m or km, and earthworks and mass transportation are based on road geometry and geology at the construction site, which in turn are based on average conditions at a county level. Examples of parameters used as basis for the calculations are: Average annual daily traffic, length and width of roads/tunnels/bridges, length of railings, height of back slope and proportion of rock along the alignment. The underlying assumptions for these calculations are based on NPRA handbooks, empirical data and previous research. The tool facilitates reduction of climate emissions through strategic choices like route alignment, e.g. road around a mountain versus tunnel, choice of main material in bridge deck, maintenance strategies etc. These are the big decisions that can have great effect on the overall climate change impact. The coefficients of CO\(_2\) emissions and accumulated energy used in the tool are calculated by applying LCA in line with ISO 14040:2006.

Development of Climate Module in EFFEKT

The inventories would benefit from being more detailed. In particular, the inventories for bridges and the calculations on diesel consumption in the construction phase are quite uncertain. One possible solution is to apply inventories from the Method for generic road and rail elements that are applicable within the framework of EFFEKT.

2.2.2 VEGLCA

VegLCA (RoadLCA) is an MS Excel–based calculation tool developed in 2015 for the NPRA. It is designed for use at a late stage of the road planning process (design and contract phase), when material amounts are available with a high level of detail. The tool is built in accordance with the same hierarchic structure used by road planners and entrepreneurs for calculating economic budgets (known as the process code). This makes the tool highly intuitive and easy to use for road planners. For some inputs, calculation factors are used for calculating amounts of materials used (for example, the input length of railings requires a factor for material use per unit length). Default values for such factors are implemented in the tool, but can be overrun by the user in the cases where specific factors are known. The same is true for inputs like transport distances for earth/rock masses and input materials, energy use in operation, frequency of maintenance operations, energy use in construction equipment, etc. It is also possible to use project specific emission intensities (e.g. EPD data). VegLCA allows environmental optimisation at a detailed level, regarding material choices in components and road layers, transport distances for earth
and rock masses, bridge and tunnel designs, construction equipment and technologies, operation and maintenance strategies and more. VegLCA can also be implemented in tenders, making environmental impact budgeting part of the decision basis in the road administrations procurements.

The figures below show a selection of the input sheet for bridges and quays (Figure 5) and a selection of the result summary sheet (Figure 6).

![Figure 5. A selection of the input sheet for bridges and quays, VegLCA](image)

<table>
<thead>
<tr>
<th>MOVEDPROSESSE ØR: BRUER OG KÆRER</th>
<th>Bruer totalt</th>
<th>Brø 1</th>
<th>Brø 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Størrelse, stødbredde</td>
<td>550 m</td>
<td>500 m</td>
<td>550 m</td>
</tr>
<tr>
<td>Mengde, takt</td>
<td>Mengde, takt</td>
<td>Mengde, takt</td>
<td>Mengde, takt</td>
</tr>
<tr>
<td>BS - LOGMASSER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS - BERG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS - KONSTRUKSJONER I GRUNNEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS - BETONG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Feedback from users

H. O. Fjeldheim, advisor at SKANSKA, who has tested VegLCA for one road project:

VegLCA is basically a very useful tool. The structure in accordance with the process codes makes the tool very effective if you have data available in this format. However, the tool is best applicable to as-built road infrastructures. It is less suitable for evaluating alternatives because data at the process code level is often calculated after decisions have been made. It might be an idea to assemble results from a wide range of road projects, for use in future planning of road projects.

Suggested improvements:

- There are some challenges related to “Hovedprosess 08: Broer og kaier” (“Main process 08: Bridges and piers”), as this is not limited to bridges and piers in practice, but all road constructions besides open road sections and tunnels (e.g. tunnel portals and soil tunnels). This opens for possible misinterpretations of the results regarding environmental impacts from road constructions.
- A possible advantageous addition to the tool could be a method for visualisation of reduction due to for instance re-use of asphalt.
- It should be possible to choose between more material qualities. In many cases, there are several types of concrete and construction steel, which are not among the alternatives in the tool.
In September 2016, a workshop on VegLCA was carried for road planners from entrepreneurs and the NPRA. The participants were given an exercise in which they were instructed to use data for a road project given on the process code format to conduct an assessment using VegLCA. Some feedbacks from this were that the tool is intuitive and easy to navigate through. However, the same issues on Process code 08 as cited from H. O. Fjeldheim above were mentioned.

Feedback from Håvard Bergsdal, Asplan Viak, on applying VegLCA on a rail project:

VegLCA can partly be applied for rail projects, as the same process codes are used for parts of the rail infrastructure. Missing elements for rail in VegLCA: superstructure (sleepers, rails etc), signalling systems, components for telecommunication and power supply. For some of the process codes, the units differ, and some process codes for the railway project studied, were not found. Overall impression: an expansion of VegLCA for inclusion of railways is both possible and would be a valuable addition to the railway planning process.

Development of VegLCA

The structure of VegLCA needs to be updated in accordance with the recent process code update. The challenges mentioned regarding the main process 08 should be resolved to avoid potential misinterpretation of the results. The calculations of climate effects due to land use changes should be improved.

More alternatives for choice of material qualities should be included.

2.2.3 METHOD FOR GENERIC ROAD AND RAIL ELEMENTS

A preliminary method for applying LCA at an early stage of infrastructure planning is in development, and parts of the method has been applied to infrastructure planning (examples are given below). This method includes life cycle inventories for several infrastructure elements and components, such as rail and road tunnels, selected bridge designs, road classes defined by the NPRA, railings, drainage systems, electronic components (mainly for rail infrastructure) and also selected highway crossings. The inventories are set up based on NPRA handbooks, technical drawings of bridges, empirical data and previous research. The figures below show the structure of the inventory for a tunnel (Figure 7) and examples of figures from NPRA handbooks that are used for estimation of parts of the inventory (Figure 8).

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3 Especially the handbooks N100 and N500, which gives guidelines and requirements to road and tunnel design
The method can be described as a further development and refining of the method in the EFFEKT Climate module. However, it is not easily applicable, as it has not been structured and assembled in one common software platform (e.g. SimaPro or Excel). Also, the method should be expanded to cover more infrastructure elements and components, and does not, at the current stage, cover earthworks in a satisfactory way.

Some examples of projects for which (parts of) the method has been used:
- **Tidligfase klimautredning for ny E39 (Early phase planning of the coastal route E39)**, (NPRA, 2015)
- **Miljøbudsjett for E18 Langangen – Rugtvedt (Environmental impact budget for E18 Langangen – Rugtvedt)**, (Nye Veier, 2016)
- **Klimagassvurderinger, bro over Bjørnafjorden (Climate emission budget for bridge-crossing of Bjørnafjorden)**, (NPRA, 2016)
- **Klimabudsjett for Follobanen (Climate emission budget for the Follo line)**, Norwegian rail adm., 2010–2012

As the method is not fully developed, some of the questions as responded to in Attachment 1 are not relevant, as some of the aspects have not yet been specifically defined. The answers that are given relate to the current status of the methodology.

**Development of generic road and rail element**
This should be further developed and structured into an easy-to-use tool, with possibilities of varying for instance design, technology, material choices and operation and maintenance
strategies. It should ideally allow for comparison of different infrastructure projects, and perhaps for comparison of road and rail transport. As this has the potential to be used at an early planning stage, with a relatively good level of detail, it should comprise many alternatives regarding design, technologies, material qualities etc., to make for a valuable tool in decision-making.

This method, if fully developed, would be ideal to integrate with a BIM tool.
2.3 SWEDISH TOOLS

2.3.1 EKA

EKA is a LCA tool in Swedish, developed for the Swedish Transport Administration (STA) and adapted for Swedish coating types and technologies. EKA is short for "Energi och Koldioxid i Asfaltsproduktion", meaning "Energy and Carbon dioxide in production of Asphalt". STA have been using the tool for some years and it will be free to download from STA before end of 2017.

The tool EKA arose from the project Energy efficient asphalt coatings (2012–2014), where STA, entrepreneurs and the asphalt industry were participants. The EKA calculation model is systematically compiled and follow the construction process in the same way that cost estimate calculations do. Roger Lundberg at NCC Roads AB has developed EKA together with STA. A report\(^4\) that describes the EKA tool is available online.

The tool calculates greenhouse gas emission and the primary energy used in asphalt manufacturing – from input materials to finished coating of a road. EKA is easy to use, specific and has a high level of detail. Data input with default values are available but it’s also possible to choose specific machines, specific technical data for the machines (e.g. consumption of diesel), production rates and capacity for blasting, crushing and asphalt manufacturing. It is possible to alter type of electricity used, size of vehicle for transportation and transport length. The pictures below show the excel–based tool’s different pages: the start page where you can choose where to change input data, data input page and the result page. Figure 9 below show the different pages of the tool.

STA is using EKA with two objectives; one is to choose what type of asphalt they use in their projects; the other objective is to reduce the climate impact from asphalt production in collaboration with the industry. The basic idea was to use the tool for the maintenance of roads i.e. when a new coating is applied. The tool can also be used for the coating layer of a new road. Calculations in EKA also confirm environmental objectives set by the STA and serve another LCA tool, "Klimatkalkyl", with data regarding finishing coating of roads.

The entrepreneurs can use EKA to optimize the processes in asphalt production to minimize climate impact and energy consumption.

However, improvement of the tools is possible since only production and laying of asphalt is included in the calculation. The difference in maintenance of the different coating types is not included. If and how the material/coating is possible to reuse etc. at end of life is not included.

\(^4\) FUD-ID 4930, Trafikverket, 2015–04–17
Figure 9. From the top down, the start page, the input data of asphalt manufacturing and the result summary, EKA

Development of EKA
To further improve EKA one should focus on including maintenance to get a more complete life cycle analysis. Today the environmental benefits of production of an asphalt with a longer
lifetime or asphalt with minimal efforts to maintain or reusable asphalt are missed. Introduction of other road coatings other than asphalt would broaden the tool.

2.3.2 GEOKALKYL

Geokalkyl (meaning geological calculation) and associated documents is free to download and available from the STA’s website. A new version is planned to be released in November, 2017.

The information presented in this report was obtained during an interview with consultant Joacim Svahn at ÅF, 2017-08-21.

Geokalkyl is a GIS-tool, developed by STA and ÅF, which uses the spatial information of topography, infrastructure placement, soil depth and soil types to calculate mass balance, construction cost, energy – and CO₂e consumption. It is developed to be used in early stages of the planning process for new infrastructure in order to compare different geographical alignments of the road or railway. Geokalkyl focuses mainly on geotechnical reinforcement measures and obtaining mass balance within the infrastructure project and include the main parts of the construction. The tool supports decisions regarding alignment.

In order to make calculations using Geokalkyl basic knowledge about GIS is required. The modeling results needs to be verified by a senior geotechnical expert. The road or railway alignment is divided into segments and the results are shown in a map. Data covering soil types and depth of different soils are used to build a ground model. A construction planning road model is imported to the ground model to calculate mass balance and to calculate suggested geotechnical measures. It is possible to export the model to an excel-file where modifications can be made. Other data can be added in GIS, such as earlier field studies.

Since the results are based on height data the calculated amounts are very accurate. Geotechnical reinforcements are suggested based on the soil interpretation. If the road or railway crosses e.g. a river it suggests a bridge or other suitable measure.

An example of how the result can be reported from the program can be seen in the Figure 10 below. The corresponding figure can be made for mass balance, CO₂e or energy consumption.

Geokalkyl is easy to use with knowledge of GIS and geotechnology. The lifecycle analysis is not complete as only production and building the road or railway is included. Geokalkyl have included machine operation needed in the construction. No operation in the use phase or maintenance is included.

2.3.3 Klimatkalkyl

Klimatkalkyl is a STA tool to calculate greenhouse gas emissions and primary energy use of road and railway infrastructure. It is widely in use since 2015 and mandatory to use for projects over 50 million SEK. The tool is used in all stages of the physical planning process – plan, design and construction. The STA use Klimatkalkyl to follow-up climate reduction requirements in procurement of contractors.

The system boundaries include extraction of raw materials, processing, construction and maintenance to some extent. Transportation that is required for construction and transportation in primary and refining production is included, but transportation from primary production site to construction site is not included. That is, transportation of excavated soil and rock but transportation of building material needed for construction is not included. End of life stage and traffic is not included in the tool.

The tool is based on emission factors and resource templates for needed construction parts, materials and maintenance.

The input data needed varies on which phase of the Swedish physical planning process the project is in and how much information is available about the project at current time. Klimatkalkyl thus become more accurate as the project progresses. Material that can be used as input to the Klimatkalkyl is data from the projects financial assessments and the bill of materials. Input data can be filled in on different levels depending on project phase, where one is a very general level with different types of infrastructure parts and the other level is very
specific, where actual amounts of constructions parts is needed. Infrastructure–part level demands input in the form of length of different road and railway types, square meters of bridges, railway stations, ground reinforcement, number of lighting points, roundabouts, underground stations and intersections. The input data in the level of construction–part is in the form of cubic meter, square meter, number, meter, tone, kg, m\(^3\) of different construction materials such as steel, concrete, piles, cables and masses of soil and rock. There is also a possibility to enter the user’s own data if there is a specific material or construction part missing in the tool.

Klimatkalkyl supports decisions regarding route alignment, type of construction (concrete or steel bridge for example) and what materials or fuels to use in general. It points out what parts of the infrastructure that have big emissions of greenhouse gases and could lead to decisions that makes a climate impact.

The tool is web–based and published on the STAs website\(^6\), see Figure 11. It is accessible to anyone who wish to look at it, but an authorization is needed to save calculations inside the programme. It is possible to exchange data sets and information between actors. The folder where the climate calculation is located can be shared to others who are authorized in Klimatkalkyl and ownership of the folder can also be changed. This means client, designer and the contractor can access the climate calculation.

The tool does not need specific skills in LCA, although a more precise calculation and understanding is probably produced by someone who understands the methods of LCA. Skills in understanding the different components in the infrastructure is needed. It is therefore a user–friendly tool. The STA has a user guide published on their website, which facilitates the use. The STA owns and maintenance the tool. There are no costs for the users of the tool. The cost lies on the STA for development and maintaining of the tool.

When extracting results from Klimatkalkyl one is free to use a suitable lifetime (normally 40 or 60 years). Different projects use different lifetimes and therefor this result is only presented when printing out results from the tool.

The result presented in the working area are in three ways:

- Total CO\(_2\)e and GJ from all activities related to construction
- CO\(_2\)e and GJ from construction and reinvestment expressed per year based on the technical lifespan of all components included in the model
- CO\(_2\)e and GJ from maintenance and operation expressed per year

\(^6\) http://www.trafikverket.se/klimatkalkyl
Figure 11. From the top down the figure shows the start page, choice of project (Klimatkalkyl) and the modelling page.

Development of Klimatkalkyl

The tool could be developed further to include in use traffic, transport between construction site and production site. The accuracy of calculations differs depending on the project phase and the precision of templates for resource use could be improved. Further development regarding operation and maintenance which better shows results of improvements within projects.

2.3.4 OTHER TOOLS

Bidcon\(^7\) is an estimating program from Elecosoft used mostly in the building sector calculating costs and CO\(_2\)e for building materials. Tyréns and Elecosoft are in the process of including CO\(_2\) values for earthworks during 2017. Bidcon is a licenced product associated with a fee.

LCC–Vägöverbyggnad (LCC–Road pavement) is used primarily for cost analysis for road pavement. It also gives a result in CO\(_2\)e.

\(^7\) https://www.elecosoft.se/programvaror/bidcon
3. SUMMARY OF THE TOOLS

Summary of the tools can be seen in attachment 1, Summary of all tools.

4. SUGGESTIONS FOR FURTHER WORK

The bullets below are comments on follow-up project, as discussed at the project start meeting.

• **Translation** of tools and reports: English versions of the tools (and further development in English) and reports could be a possible solution. A common guideline for LCA calculations of infrastructure projects, given in in each country’s language, is even more needed than translating the tools. There would have to be some adjustments of the national guidelines to make this happen:
  - Defining the principles of development of the LCA-tools at Nordic level and at national level, and
  - Defining the roles of the owners of the tools and traffic agencies and other parties, and
  - Developing Nordic or national guidelines for LCA calculations and developing international standards of LCA calculations, and
  - Using available PCRs

• **Adaptation of existing tools** to the conditions in the various countries: Many conditions are rather similar. A common basis for LCA calculations is most important. See first bullet.

• Application of ISO and EN standards and data quality criteria: Data quality is very important. There were big differences in results when comparing the tools in Finland. Standards and development of standards are important, but don’t guarantee the correctness of results. A first step is to follow the same standard method, and maybe to use a common, merged database to get comparable results. See first bullet.

• Making more use of EPD’s in the tools: This is important for advanced use of LCA – but in most cases, in the near future, average emission factors are satisfactory. Product specific EPD’s are needed in special cases. But, the more EPDs that are developed, a higher quality data will be available in the databases.

• Linking LCA-tools with BIM: Linking BIM and calculation of quantities and cost in road construction is under development. The development will enable linking BIM and LCA after some further development of the data transferring standards (IFC, LandXML, InfraModel3). Linking LCA to BIM should be taken as a development proposal to the Nordic and national groups that are responsible for developing BIM standards.
• Linking LCA–tools with LCC: Many of the Swedish tools are developed with an LCC and LCA link. General LCC is used seldom. LCC principles are the basis of planning, design, construction and maintenance practises and guidelines of traffic agencies.

• Making light versions of the tools (very user friendly and 80% correct): Light version LCA tool, which takes into account 80 – 95% of the most relevant materials, transports and machinery is satisfactory in many cases. This does not apply to all tools.

• Using the tools to demonstrate the potential of LCA in general cases: Very important. More LCA calculations with clear goals are needed to demonstrate how the LCA calculations are taken into account in planning, design and procurement.

Suggestions for further work

• Developing the LCA calculation tools to decrease the bias of the calculation results (testing and comparing).
• Piloting the tools in real projects for different uses.
• Traffic emissions from infrastructure in use should be included in the assessment.
• Setting out a road map of development of utilizing LCA calculations in activities of traffic agency. Defining the development steps that are necessary to achieve the wanted goals. Possible uses of LCA would be for example comparing different solutions, guiding decisions made during planning/designing, setting limit values to for example use of natural materials or CO2 emissions, using LCA criteria as a part of quality assessment of contracts.
• One way to conform the way to calculate impact from infrastructure is to use PCR (Product Category Rules) from the International EPD® system. There are PCRs available for Railways, Highways (except elevated highways), Streets and Roads, and Bridges, elevated highways and tunnels. These are all under review and will be available at the end of 2017. These are, at the moment, seldom being used. The tools could adjusted to follow these PCRs.

5. CONCLUSIONS FROM THE WORKSHOP

The need for common guidelines appeared to be bigger than the need for common tools. Developing a common tool is not key, as the tools as they are today give the results needed. It is more important to work on a good common basis for the tools (standards and framework) in a guideline. NordLCA should therefore not focus on translating and adapting tools. However, some of the existing tools would be a valuable addition in other countries. This applies mainly EKA,

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8 CPC 53212 Railways
9 CPC 53211 Highways (except elevated highways), streets and roads
10 CPC 53221 Bridges, elevated highways and tunnels
11 http://environdec.com/en/PCR/
Geokalkyl and EPD generators. NordLCA should facilitate translating and adaptation of such tools on request.

A common basis can support the NRA’s and contractors to handle different lay-outs and to give comparable results. Different lay-outs are almost unavoidable if NRA’s prefer the same structure as in their LCC tools.

The use of different tools gives different results, due to different standards, extent and framework. To make results more reliable, usable and comparable we should set common standards and framework. Important elements are:

- PCR
- Guideline use of PCR in NRA (common principles)
- (tools to estimate) Expected lifetime of elements/projects
- Try, use, compare, share

About standards, the following questions must be answered:

- Do our tools follow standards?
- Which standards? Why?
- Why not?
- Do they need to follow standards?
- Would it be feasible to agree on using the same ones?

A road map of development of utilizing LCA calculations in activities is needed. NordLCA should define the development steps that are necessary to achieve the wanted goals.

We can benefit from sharing knowledge.

- There is a wish for more meetings like the workshop at 14.09. Continued work on common guidelines in the same grouping that produced this report in the form of some planned workshops during the NordLCA project. The proposal is that NPRA, STA and FTA are convening and calling consultants who attend workshops when needed and doing work / “homework” between workshops. Other types of experts should also be involved: BIM, LCC, contractors, plan phase experts, etc.
- A guideline, on how to obtain environmental impact reduction (e.g. CO₂-equiv. reduction) using LCA–tools (including examples), contributes to external knowledge sharing

Integration with BIM still is regarded to be the future. NordLCA should share needs and wishes with the respective BIM groups and experts in the various countries. When a standard for BIM is chosen, NordLCA should work on integrating LCA and BIM. The ultimate tool would also contain LCC.

Other long–term ideas:

- Main tools (e.g. Klimatkalkyl) contain average factors. Results can be improved by using specific factors which can be generated in e.g. EKA and Geokalkyl. An integrated tool where factors are improved automatically could be an improvement.
- Including impact of in use traffic in our tools would be a valuable improvement.