REDUCING GHG EMISSIONS: AN ASSESSMENT TOOL FOR ROAD PROJECTS

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Abstract

No sector can afford today to ignore the ecological repercussions of its own activities and of the growing potential for enhancing positive while reducing negative impacts. Alongside other industries, the road infrastructure sector is assuming with great responsibility the challenges ahead. The development of monitoring and assessment tools has been part of this endeavor and an effective way to implement the low carbon transportation strategies set up by governments. The paper provides an overview of structure and functionalities of the greenhouse gas calculator that the International Road Federation (IRF) has designed - together with a number of technical partners – to specifically assess road infrastructure projects. Based on an input/output modeling approach, the tool enables both public and private entities to monitor and assess GHG emissions generated during the various stages of the road construction process. The ultimate purpose of this tool is multifaceted: 1. Facilitating a detailed environmental analysis of road projects; 2. Providing a basis for comparative analysis of various road-building techniques and materials; 3. Optimising road construction site supply schemes with respect to raw material providers, choice of suppliers, delivery locations and material transport modes; 4. Enabling an estimation of the carbon footprint of road construction activities. Developed in the form of a software, the tool currently comprises two main modules: Pre-construction and Pavement. The tool has been run on a number of different projects around the world. The paper provides in particular the result of some experiences with projects in India.

1. THE CLIMATE CHANGE CHALLENGE

Climate change resulting from human activities is recognised as one of the most urgent environmental issues facing the global community. No sector can afford today to ignore the ecological repercussions of its own activities and of the growing potential for enhancing positive while reducing negative impacts. Representing around 15% of global GHG and 23% of energy-related carbon dioxide (CO2) emissions (OECD/ITF 2010) – which are expected to rise faster than other sectors - the transport sector is certainly not an exception. It clearly has the scope and means to make decisive contributions in terms of championing more eco-friendly techniques and technologies. Alongside other industries, the road infrastructure sector is assuming with great responsibility the challenges ahead. The development of emissions monitoring and assessment tools has been part of this endeavor and an effective way to translate into reality the low carbon transportation strategies set up by governments. Up to now, however, what has been lacking is a common methodology, offering a credible and universally accepted system of measurement for defining strategy and monitoring progress. CHANGER (Calculator for Harmonised Assessment and Normalisation of Greeehouse-gas Emissions for Roads) – developed by the International Road Federation marks a contribution in changing this situation.

2. A CALCULATION TOOL FOR ROAD CONSTRUCTION PROJECTS

Committed to the green economy and to being at the forefront of global efforts to stimulate change for a sustainable future, the International Road Federation (IRF) has designed a greenhouse gas calculator specifically tailored to road infrastructure projects. The tool takes the form of a user-friendly software that enables both public and private entities to monitor and assess GHG emissions generated during the various stages of the road construction process.

2.1 Objectives

The main objective of this project are to achieve tangible, long-term benefits for the global environment and to contribute proactively to the shaping of dynamic sustainable road development policies going forward.

The ultimate goal of the tool is multifaceted:

- Facilitating a detailed environmental analysis of road projects;
- Providing a basis for comparative analysis of various road-building techniques and materials;
- Optimising road construction site supply schemes with respect to raw material providers, choice of suppliers, delivery locations and material transport modes;
- Enabling an estimation of the carbon footprint of road construction activities.

2.2 Concept and Modelling approach

A carbon footprint is a measure of the carbon dioxide (and other potential greenhouse gases) arising as a result of a specified activity or product. Quantifying the carbon footprint of an activity or product allows the sources of the impacts to be understood, investigated and managed.

Carbon footprinting is an emerging technique. It is not an exact science, it is a modelling exercise. Decisions and assumptions have to be made about the nature of the systems being investigated and modelled. Although guidelines have been developed by different entities around the world, there is currently no internationally defined and agreed carbon footprinting methodology. Broadly, the techniques required in carbon footprinting are generally similar to those of energy analysis and life cycle assessment (LCA). The International Standards for life cycle assessment (ISO 14040 series on Environmental Management) are non-prescriptive, providing a framework for LCA practitioners rather than setting rigid rules and prescribing the datasets to be used.

The tool adopts a comprehensive “input-output” modelling approach. The calculation model is based on a set of equations that enable accurate estimation of overall GHG emissions (outputs) generated by each identified and quantified source (inputs).

2.3 Structure and boundaries

The tool currently comprises two main modules (Figure 1):

- Pre-construction (clearing and piling, cut export and fill import transport)
- Pavement (on-site impacts, construction materials, materials transport, construction machines).

The scope of the model does not include – at the moment – maintenance activities, provision and powering of street lighting, any road marking or road signage, any impact associated with using the road.

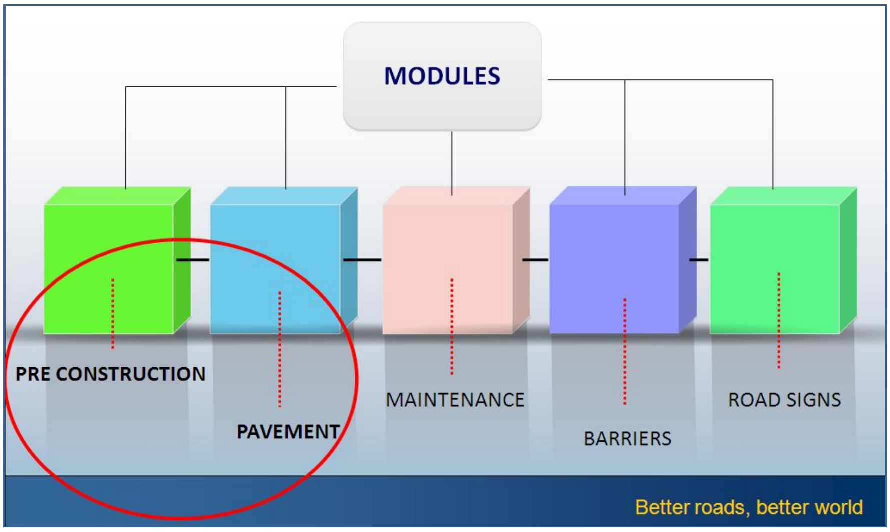

Figure 1 – The Modules

Every module follows the same logical stages (Figure 2).

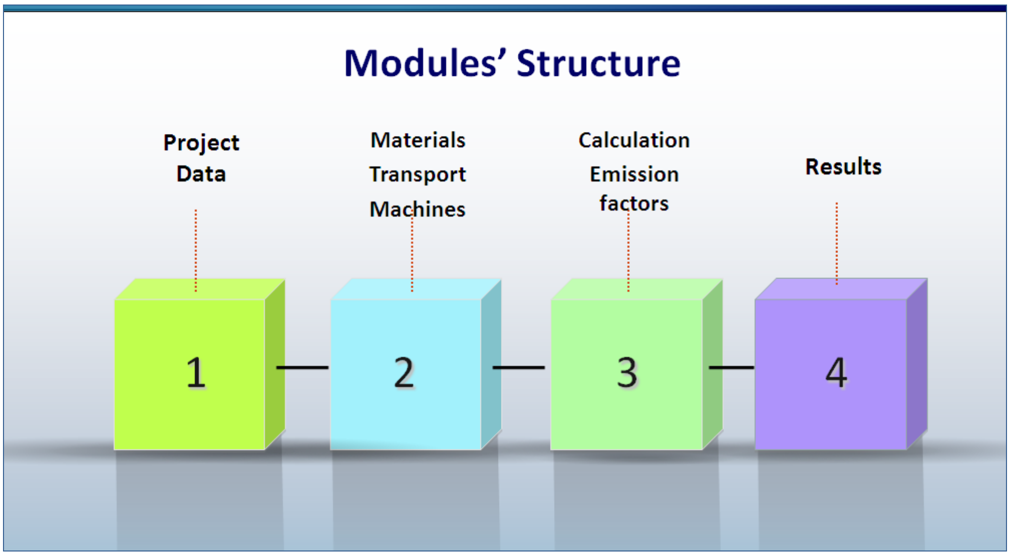

Figure 2 – Modules' structure

Firstly, input data on the characteristics of the project is entered by the user of the calculator. Then, materials and energy flow are quantified. These quantities are then assessed with emissions factors in order to output the total GHG emissions attributable to the road construction process. The effects of specifically three greenhouse gases have been considered – wherever possible – in the calculation: carbon dioxide (CO_{2}), nitrous oxide (N_2O), and methane (CH_4). Once assessed, these GHG emissions are converted to carbon dioxide equivalent. There are six main greenhouse gases which cause climate change and are limited by the Kyoto Protocol. Each gas has a different global warming potential. For simplicity of reporting, the mass of each gas emitted is commonly translated into CO_2Eq amount so that the total impact from all sources can be summed to one figure (Carbon Trust, 2007). A simple calculation methodology has been developed by the IPCC and is widely accepted in order to compare the contribution of the gases to global warming. The values attributed to the gases are updated periodically.

Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalent" (MMTCO_2Eq).

GHG	GWP Factor (100 years)	Comment
Carbon dioxide(CO_2)	1	This is the reference unit against which all other GHG emissions are benchmarked
Methane (CH_4)	21	Methane is 21x more potent than carbon dioxide as a greenhouse gas. This means that 1 kg of methane has a global warming potential of 21kg CO2e
Nitrous oxide (N_2O)	310	Nitrous oxide (N20) 310 Nitrous oxide is 310x more potent than carbon dioxide as a greenhouse gas. This means that 1 kg of nitrous oxide has a global warming potential of 310kg CO2e

Table 1 - Global warming potential (GWP) factors applied

The research has been organised in a series of successive and interlinked stages:

- Compilation of an exhaustive inventory of GHG emission sources by reference to the different stages of road infrastructure construction;
- Estimation of the level of intensity to be applied for evaluation of the emissions sources thus identified;
- Research and compilation of the applicable emissions factors, in accordance with guidelines provided by the Intergovernmental Panel on Climate Change (IPCC).
- Set up of the equation for the calculation:

$$\textit{Emissions} = \Sigma S_i * \textit{Emission Factor with } S_i = \textit{Source } (A*I)_i$$

where sources are specified in units compatible with the emission coefficient; A = activity level and I = intensity.

Emission factors have been sourced from a number of resources (see references section for an indication of the main sources). Only readily available emission factors from secondary sources have been applied, no primary data has been collected or developed. The Inventory of Carbon and Energy (ICE) of the University of Bath (1.6a version) was the main source used for embodied energy and carbon coefficients for building materials. The boundary conditions for each material are specified within the material profiles in the inventory. Cradle-to-Gate was the most commonly specified boundary condition. As clarified in the Inventory of the University of Bath, "The embodied energy (Carbon) of a building material can be taken as the total primary energy consumed (carbon released) over its life cycle. This would normally include (at least) extraction, manufacturing and transportation. Ideally the boundaries would be set from the extraction of raw materials until the end of the products life-time (including energy from manufacturing, transport, energy to manufacture capital equipment, heating & lighting of factory, maintenance, disposal, etc.), Known as "Cradle-to-Grave. It has become common practice to specify the embodied energy as "Cradle-to-Gate", which includes all energy (in primary form) until the product leaves the factory gate. The final boundary condition is "Cradle-to-Site", which includes all of the energy consumed until the product has reached the point of use (i.e. building site)".

2.4 Functionalities

The pre-construction module takes into account:

- *Clearing and piling*: based on the ground surface area cleared per unit of road surface, an estimation can be generated for both machine use and fuel consumption. Transportation of trees removed is also taken into account (the tool does not account for either the loss of CO2 absorption by the removed trees or for their replacement with new or replanted trees in the areas concerned).
- *Cut exports and fill imports transport* to and from the road site: based on a simplified diagram, the user selects the relevant sites and enters the respective distances, tons of material and transport modes (road, rail or inland water).

The pavement module takes into account:

- *On-site impacts*: electricity and fuel consumption on the construction site as identified and evaluated.

- *Pavement construction materials*: this section encompasses several menus (unbound materials, hydraulically bound materials, bituminous bound materials, metals, rubber and plastic, etc.), from which the user can easily select the materials required for construction of the different layers of the given pavement.

- *Materials transport*: a simplified diagram has been set up to help visualise and assess the emissions generated by transportation of the materials identified (Figure 3):

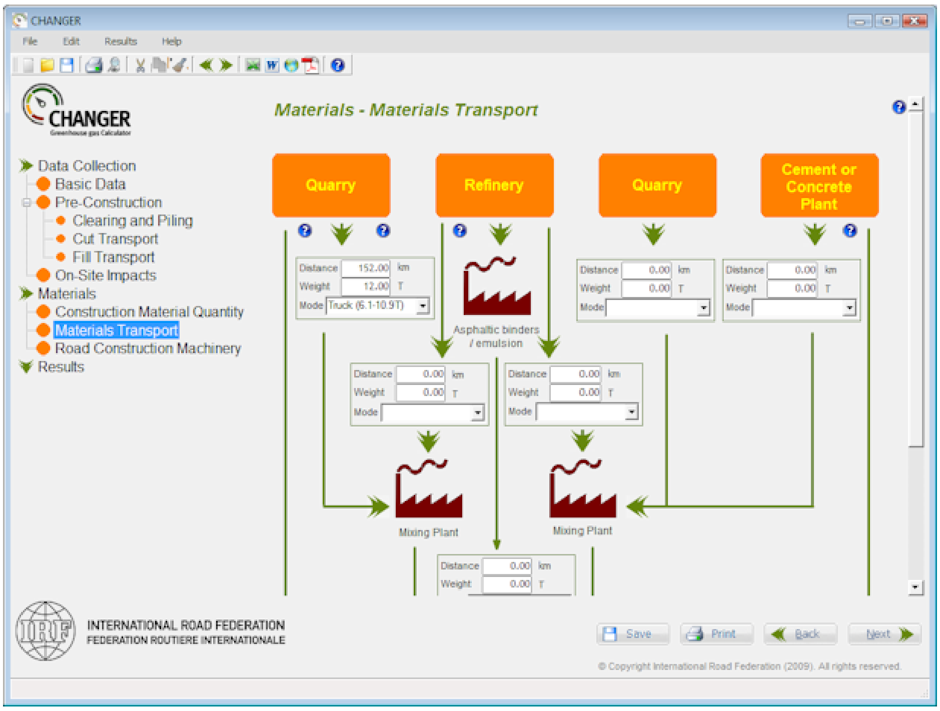

Figure 3 – Materials' Transport Diagram

- For aggregates: two possible quarry sites are considered. Aggregates are transported either directly to the road site (granular materials for sub-base and filter drain) or first to the mixing plants (granular materials used for mixtures) and then to the road site;
- For bituminous materials: the system considers bitumen transport from the refinery to two possible mixing plant sites, and then from the plants to the road site. The model also accounts for the transport of emulsions directly from refinery to site;

- For cement: the system caters for both transport of cement directly to the site or via a mixing plant.
- For concrete: transport of concrete directly to the road site is similarly included as an option.

- *Construction machines*: The model estimates the number of working hours per type of machine and number of pavement layer. The total consumption of fuel is determined on the basis of the characteristics and efficiency of the material used.

Dropdown menus and data entry wizards are designed to enhance user-friendliness at every stage. More over, CHANGER automatically generates comprehensive reports – either aggregated (total) or disaggregated (inherent to only one or more steps of the process) – that can be conveniently exported to Excel, Word, PDF and HTML (Figure 4).

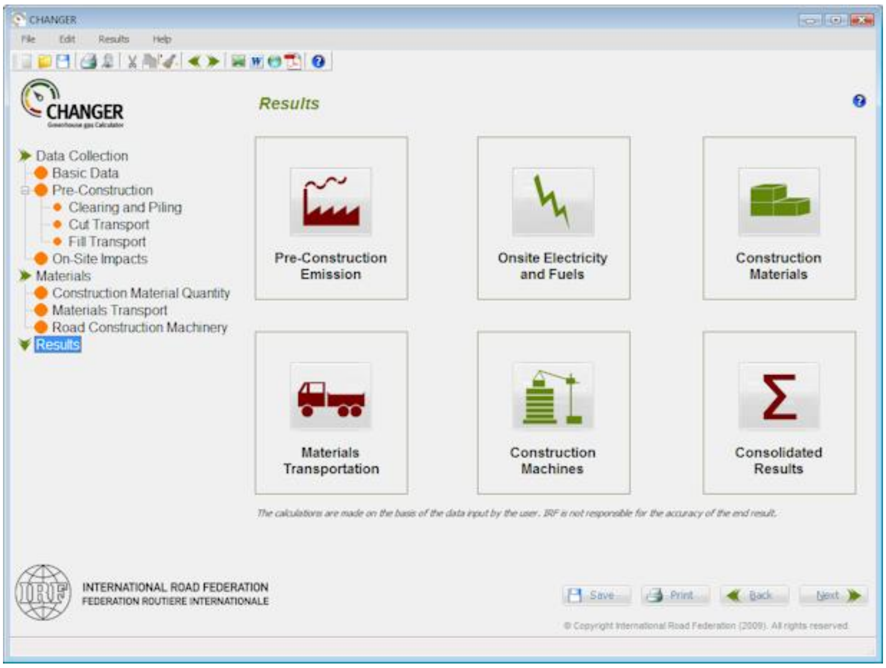

Figure 4 - Results

2.5 Validation process

By virtue of its extensive and varied membership – both in terms of geographical coverage and fields of specialisation – IRF has benefited from technical support from a wide range of industry and technical partners throughout the development of the project. This has been particularly invaluable for ongoing review and validation of the modelling approach and databases, as well as for testing and comparison.

The LAVOC (Traffic Facilities Laboratory) of the Swiss Federal Institute of Technology (Ecole Polytechnique Fédérale de Lausanne - EPFL) has analysed and validated both the quality and reliability of the databases and the calculation procedures.

2.6 Future development and updates

CHANGER has been conceived as an evolving tool, subject to ongoing review and development so that it ultimately covers every phase and aspect of road construction. Already, work is underway on complementing the existing pre-construction and pavement modules with a new module devoted to maintenance activities. Similarly, the databases will be regularly updated to reflect the very latest science as well as cutting-edge research on techniques, materials and equipment. Updates are made available to the users directly on the dedicated website.

3. AN EXAMPLE OF RESULTS OBTAINED IN INDIA

The Karnataka State Highways Improvement Project (KSHIP) is an initiative by the Public Works Department (PWD) of the Government of Karnataka (GOK), to undertake improvement of roads consisting of State Highways and Major District Roads. Total of 4887.5 km stretch of the roads were selected on the basis of a Strategic Option Study (SOS). Based on the Feasibility study, the GoK has selected 268.59 km of roads for up gradation in a phased manner under KSHIP-II, EPC. The proposed project is grouped into five contract packages consisting of eight road links spread across the state of Karnataka state, India. The Project plays a an important role in the development of state and the significance of good roads in the state's quest for infrastructure. The project is promoting sustainability in highway construction to focus on innovative standards and development activities. As a proactive measure an attempt has been made to quantify the GHG emissions by using CHANGER on five projects.
The following results were obtained:

Project	Link	Description	Length (km)	Package length (km)	CO2-eq emissions (t)	CO2-eq per km (t)
WEP1	67A	Hoskote - H Cross (Hindagnala Cross)	23.50	**52.40**	**169,132**	**3,228**
	67B	H Cross (Hindagnala Cross) - Chintamani Bypass	28.90			
WEP2	T8	Haveri (NH4) - Hangal	31.80	**75.26**	**67,500**	**897**
	M7D	Hangal - Tadasa	43.46			
WEP3	21B	Dharwad - Saundatti	38.50	**38.50**	**60,631**	**1,575**
WEP4	13A	Tinthni - Devadurga	32.45	**73.80**	**92,041**	**1,247**
	13B	Devadurga - Kalmala	41.35			
WEP5	6C	Chowdapur - Gulbarga	28.63	**28.63**	**46,870**	**1,637**

Table 2 – Results obtained in India

CO2-eq per km (t) for the proposed project packages varies between 897 tons for WEP2 to 3228 tons for WEP1. Variation in results for CO2-eq per km of different sub-projects is due to following reasons.

- Variation in quantities of required construction materials from project to project depending on the length of the road and cross section of the road projects.
- Variation in lead distances for construction materials from project to project depending on sourcing of the raw materials and the location of project.
- Number of cross drainage structures and length of lined drains for five projects varies based on the project requirements.

In addition to the above, factors such as the projected traffic dictating the pavement type and thickness, foundation strength; location and geology; existing road layout and pavement condition; drainage type and quantity of structures and land acquisition also have their share in the variation of results.
The results of case studies indicate that the production and transport of the materials used in road constructions produce the most significant environmental burdens. Production of the bitumen and cement, crushing of materials and transport of materials are the most energy consuming single life-cycle stages of the construction.

4. CONCLUSIONS

Governments will be increasingly required to submit regular GHG emission accounts as part of their international commitments in particular under the UN Climate Change Convention. Every sector is coming under pressure to evaluate current activities, practices and potential to reduce emissions. Leading international financial institutions are also progressively looking at ways to include compulsory GHG assessment of road construction projects in their tendering procedures. Up until now what has been lacking is a common methodology offering a credible and universally accepted system of measurement for defining strategy and monitoring progress. CHANGER contributes to this common effort by offering to both the public and the private sector a “clear path” methodology simplifying the processing and analysis of complex technical information. Looking forward, the methodology applied needs of course to be further developed to include all relevant activities inherent to the life-cycle of road infrastructure. Further work is required to improve the carbon footprint estimates of road transport by including in particular the impacts associated with the using of the road (vehicle emissions) which do represent the bulk of emissions produced by the sector. The bottom line is to allow the carbon impact of roads provision to be considered and managed on an informative and quantitative basis.

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