XIX SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '20

NOVEL RECOMMENDATIONS OF UIC FOR CALCULATION OF CARBON CONTENT IN RAILWAY INFRASTRUCTURE

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Abstract – *The quantifaing carbon emissions from the rail sector has a long history because railways are among the all transport modes, one of efficient modes of carbon mass transportation. According to UIC's recomendations all rail operators need to lowering the carbon impact of the railway sector. The most approaches are harmonized except evaluation and estimation of the carbon content of the railway infrastructure over its life cycle. The aim of this paper is to present novel UIC's recomendation for evaluation the carbon footprint of railway infrastructure. The novelty of the carbon footprint estimation is consideration of building and maintance of railway infrastructure and construction vehicles/machines used for those purpose that usually emit significant amounts of carbon. Also we discused the role of certification process,i.e. the necesserity of implementation regulations such as ISO 14064 standard that provides set of tools for programs to quantify, monitor, report and verify greenhouse gas emissions.*

Key words – Carbon footprint, railway infrastructure, methods.

1. INTRODUCTION

Greenhouse gaseous GHGs are constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. CO_2 is the major greenhouse gas contributing to global warming and climate change; it is emitted by both natural and anthropogenic sources.

The Kyoto Protocol [1] regulates five GHGs beside carbon dioxide: methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

The Intergovernmental Panel on Climate Change (IPCC) [2] claims that warming of the climate system “is unequivocal”. Global greenhouse gas (GHG) emissions [3] due to human activities have grown since pre-industrial times, with an increase of 70 % between 1970 and 2004 alone. This development has led to clear changes in temperatures. An additional temperature rise of between 1°C and 4°C is projected between 2000-2100, depending on the level of stabilization of GHG emissions.

The transport sector is projected to remain the fastest growing sector when it comes to CO_2 emissions. Green house gases are generated from all types of railway locomotive and diesel combustion contributes the maximum. Emissions from an individual railway locomotive will depend on the fuel used, full carbon content of the fuel, distance travelled, cargo load, passenger load and engine efficiency. In the context of increasing global awareness of anthropogenic climate change, the carbon footprint concept is now widely used both as a marketing tool and to mobilize public sentiment. The Europian Investment Bank (EIB) considered carbon footprint methodology as “work in progress” that is subjected to periodic review and revision in the light

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of experience gained and as knowledge of climate change issues evolves [4].

The railways are one of the most environment-friendly means of transport. Modal shift towards rail transport can be an appropriate measure for reducing energy consumption, CO_2 emissions, pollutants and noise. The advantages of rail transport are most prominent in terms of energy efficiency and reduction of environmental impact.

In the case of passenger transport, the railways emit less CO_2 than, for example, private cars by a factor of between 2 and 4, depending on the concrete technology, the occupancy rate, and the energy mix in the catenaries [5]. Therefore, modal shift towards the railways is an important means of climate policy. However, the railways themselves can also become more efficient in terms of energy consumption and CO_2 emissions. Reducing the CO_2 emissions of the railways directly contributes to climate protection.

2. ENERGY CONSUMPTION AND CO_2 EMISSIONS

Energy consumption is directly connected with GHG emissions that are expressed via CO_2 emissions or total carbon emission.

After carbon dioxide, black carbon[1] has the second biggest impact on climate forcing in the atmosphere. Black carbon typically remains in the atmosphere for days to weeks, until it returns to the earth's surface through rain or air deposition [6-9]. Carbon dioxide, in contrast, stays in the atmosphere for decades. While in the atmosphere, black carbon has over 3,000 times the global warming potential (GWP) of carbon dioxide, black carbon has a number of harmful qualities, but also the potential for reduction. On a global scale, the largest sources of black carbon are open burning of grasses, woodlands and forests (as well as agricultural fields to a lesser degree), residential heating and cooking (primarily from wood fires), and diesel engines [10].

The primary sources of carbon black are on-road and off-road diesel engines. On-road diesel engines include diesel trucks, cars, etc. Off-road diesel engines include locomotives and other heavy-duty equipment, thus the share related to freight transport (e.g., trains, ships, agricultural and construction equipment, generators, etc.).

[1] Black carbon is a distinct type of carbonaceous material that is formed primarily in flames, is directly emitted to the atmosphere, and has a unique combination of physical properties. It strongly absorbs visible light, is refractory with a vaporization temperature near 4000 K, exists as an aggregate of small spheres, and is insoluble in water and common organic solvents. Sources whose emissions are rich in black carbon ("BC-rich") can be grouped into a small number of categories, broadly described as diesel engines, industry, residential solid fuel, and open burning.

Railway specific energy consumption and specific CO_2 emissions are mainly based on UIC data. The railway companies provide UIC with their tractive stock's total energy consumption split by electric/diesel and passenger/freight activity. These total energy consumptions are combined with pkm and tkm data (allocated to diesel and electricity according to the repartition of passenger and freight train-km), allowing the calculation of energy intensities for passenger and freight activity where company data are available. Unfortunately the carbon content from railway inrastructure, i.e. building and maintance of railway infrastructure and construction vehicles/machines used for those purpose that usually emit significant amounts of carbon, is not included.

Currently, reporting companies use one of the IPCC based approaches to estimate emissions from their rail transport that are variations of the same fundamental equation:

$$E = F_C \times E_F \qquad (1)$$

Where:
E - emission,
F_C - fuel consumption,
E_F - emission factor.

The first approach, emissions estimated using fuel-specific default emission factors, assume that for each fuel type a single locomotive type consumes the total fuel. The second approach uses country-specific data on the carbon content of the fuel for different types of locomotives. The emission factors arrived at is to be specific to broad locomotive technology type. The third approach involves a more detailed modeling of the usage of each type of engine and train, which will affect emissions through dependence of emission factors on load. Data needed includes the fuel consumption which can be stratified according to typical journey and kilometers travelled by the train.

3. EMISSION FACTORS

For easier calculation infrastructure carbon footprint may be evaluated through four different phases: design, construction, operation and disposal. Planning railway construction is a shorter phase in terms of time compared to the life time of the infrastructure and mainly requires computers in engineering offices. Building railway tracks requires material production, transport and machines operating intensively for several years to adapt the topography to the rail line needs. All of these activites demands energy consumtion and consequetly carbon intensive emission. Maintenance requires machines and operation that usually emit significant amounts of carbon. Removing rail infrastructure tracks and all related material usually required machines powered by diesel producing significant amounts of carbon emissions.

Two existing standards have been adopted in the UICs proposed methodologies, ISO 14000 series, particularly ISO 14064 an GHG protocol a new standard that allow national approach for carbon content quantification.

Emission factors for each vehicle type may be determined via:

- CO_2 eq. Emissions / Passenger - km,
- CO_2 eq. Emissions / Ton – km.

Methodologies commonly used to determine Rail emission factors utilize the methodology using the following input data:

- Fuel consumed (diesel/electricity),
- Passenger km travelled,
- Freight transported (ton-km),
- National emission factors for fuel used.

Methodology for calculation using total fuel consumed by railway sector proposes arriving at rail transport emission factor when the overall energy consumption of the railway sector is available. It involves estimating the specific power/fuel consumption of rail transport (when no information on fuel split between passenger and freight trains is available but the total energy consumption by rail traction is known). This fuel consumption is then converted to emissions using the fuels' calorific value and emission factors. Emissions are then allocated to passenger and freight transport on a weighted average basis using distance performed as shown below:

$$\text{OVERALL EMISSIONS} = (D_c \times C_v \times D \times E_f) + (E_u \times N_{ef}) \quad (2)$$

Where:
D_c -total diesel consumed,
C_v - calorific value,
D - density,
E_f - emission factor,
E_u - electricity usage,
N_{ef} - national grid emission factor.

Emission factor CO_2 eq. emissionsper passenger and freight, could be estimated as follow:

$$\frac{CO_2\ \text{eq.Emissions}}{\text{Passenger}-\text{km}} = \frac{\text{Overall emissions}}{\text{passenger km performed}} \quad (3)$$

$$\frac{CO_2\ \text{eq.Emissions}}{\text{Ton}-\text{km}} = \frac{\text{Overall emissions}}{\text{freight ton}-\text{km performed}} \quad (4)$$

As black carbon always follow CO_2 emission, as a product of fuel consumption by diesel engines used in rail transport and in machinery for infrastructure building and maintaining that must have be under consideration in calculation of emission associated with fuel burned data.

The following equation can be used to calculate black carbon emissions with actual fuel burn data. Different fuel types should be calculated separately.

$$\text{Black carbon (g)} = \text{fuel (kg)} \times \text{black carbon em. factor} \left(\frac{\text{black carbon (g)}}{\text{fuel (kg)}}\right) \quad (5)$$

Black carbon is generally classified under the umbrella category of particulate matter (PM). In terms of air quality regulations, PMs are commonly divided by particle size: under 2.5 micrometers in diameter (PM2.5) and particles under 10 micrometers (PM10). For transport, 98% of PM emissions are within the category of PM2.5. PM2.5 emissions factors can be converted to black carbon using a PM2.5 speciation factor, as shown in Equation 6.

$$\text{Black carbon (g)} = \text{fuel (kg)} \times \left[\text{PM2.5 emissions factor} \left(\frac{\text{g BC}}{\text{g PM2.5}}\right) \times \text{PM2.5 speciation factor} \left(\frac{\text{PM2.5 (g)}}{\text{fuel (kg)}}\right)\right] \quad (6)$$

4. CONCLUSION

International Union of Railways (UIC) has published the “Carbon Footprint of High Speed Rail: Final Report” [11] presenting the results of a carbon footprint analysis. Earthwork, transport of construction materials, engineering structures, like bridges and tunnels, rolling stock manufacture, electrical and signaling equipment have been taken into account in the construction analysis. The total emissions from the construction of the high-speed rail are in the range of 58–156 $tCO_2\ km^{-1}$ of line $year^{-1}$. The results from the comparison of the road and rail transport systems highlight many interesting issues. However, the railway system operation is more environmentally friendly than the highway system operation.

Carbon footprint analysis would provide tools for sustainable development of infrastructure construction as well as deciding on alternate models of construction. The choice of materials and techniques in transport construction is dictated not only by structural requirements and economic aspects but also by environmental factors that have also gained in importance due to ecological considerations in politics.

The rail infrastructure is made up of a number of elements (track with ballast) including stations, tunnels, bridges, signaling and telecommunications. Including the carbon footprint of railway infrastructure in the eco calculations would reward those making an effort to mitigate carbon emissions over the construction, re-construction and re-building of the line by using more carbon friendly techniques. It would create a win-win situation, where the rail sector reinforces its sustainability lead, and where infrastructure and railway operators are further committed to reduce CO_2 emissions, and evaluating possible advantages of investments in railways as a solution to reduce carbon footprint in transport.

ACKNOWLEDGEMENT

This work was financially supported by Ministry of education, science and technological development of the Republic of Serbia under the research project: ON172015.

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