INDIA GHG PROGRAM

Promoting profitable, sustainable and competitive businesses.

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India Specific Rail Transport Emission Factors for Passenger Travel and Material Transport

For Stakeholder Consultation

http://indiaghgp.org

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While every care has been taken in writing the technical paper, India GHG Program and supporting organizations accept no claim for compensation with respect to any wrong, abbreviated, omitted or incorrectly inserted content in the book. The paper is only an attempt to estimate the emission factor.

The technical paper has been compiled based upon the publicly available data.

The paper is open for stakeholder consultation and you are invited to share your views and comments to Mr Chirag Gajjar (cgajjar@wri.org) / Mr Atik Sheikh (atik.sheikh@cii.in).

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Executive Summary

India has the largest rail network in Asia and also second largest under single management, with a total route network of about 64,460 km spread across 8,241 stations (2011)[1]. It operates more than 19,000 trains, 229,381 wagons, 59,713 coaches and 8,417 locomotives every day. The Indian Railways moves more than 1,000 million tonnes of freight annually, making it one of the busiest rail networks in the world. Moreover, it is reported to have transported a staggering 8,397 million passengers in 2013-14[2]. As a consequence, large amount of Green House Gases (GHGs) are emitted due to the combustion of diesel, consumption of electricity and use of other liquid fuels. The railways emitted 6.84 million tons of CO_2 eq. in 2007, in which more than 90% of the emissions were in the form of CO_2[3]. Given its growth, the railway sector is a growing source of GHG emissions. However, it is still less emission intensive as compared to air and road transport sectors. Since climate change is a central element in all economic decision making/choices, rail becomes the most appreciable alternative.

The business commute by rail can be one of the major source of GHG emissions for organizations undertaking GHG inventory. The GHG Protocol includes this under Scope 3 – commute, material and fuel transport category, for the reporting company. Companies have started expanding their sphere of accounting to include scope 3 emissions and are now including the emissions from material transport and commute by rail in their inventory.

The organizations while undertaking the estimation of GHG emission refer to the internationally available emissions factor. International factors that are currently in use may not be representative of the Indian scenario and reporting companies make assumptions for estimation. This brings inconsistency in the approach thereby questioning the reliability of emission figures. In India, emission factors specific to rail transport prevailing with Indian conditions is unavailable. However, the challenge remains in identifying India specific emission factors.

This study aims to determine a methodology to estimate India specific rail transport emission factors to aid the Indian corporate strengthen its GHG accounting process and explore GHG reduction opportunities in scope 3 category.

[1]Indian Railways Annual Report -2013-14
[2]Indian Railways
[3]INCCA Report 2007

The methodology has been arrived with detailed consultation from Working Group formed for the India Specific Rail Transport Emission Factors. The working group comprised of key stakeholders from the Indian Railways Sector. The working group provided their valuable inputs to establish and refine the methodology to arrive at emission factors through various meetings, tele-conferences and discussions.

India GHG Program acknowledges with thanks the co-operation extended and the valuable inputs provided by the working group members.

Working Group Members:

- Indian Railways
- National Thermal Power Plant Corporation Limited (NTPC)
- Indian Oil Corporation Limited (IOCL)

Summary of activities by the working group:

- Review of the existing international and national methodologies and emission factors
- Identify the methodology to arrive at country specific emission factors
- Identify stakeholders & their level of involvement

Based on the inputs from the working group, and by using the proposed methodology and data available in the public domain, the emission factors estimated is as shown below

2012-13

Passenger Transport: (kg CO2 / Passenger – km)
1.Non-Suburban - 0.00794
2.Suburban – 0.00795

Material Transport: 0.0095 kg CO_2 / Ton – km)

2014-15

Passenger Transport: (kg CO2 / Passenger – km)
1.Non-Suburban - 0.007837
2.Suburban – 0.007976

Material Transport: 0.00996 kg CO_2 / Ton – km)

Limitation:

- The emissions factors are specifically for Indian Railways (Suburban and Non Suburban) and freight. These emission factors are not applicable to Mass Rapid Transportation System (MRTS)
- Allocation of emissions from general compartments, air conditioned compartments and economy class have not been considered. This remains a challenge at this point due to the unavailability of breakup in the public domain.

This paper includes the following:

1) Methodology that has been followed internationally to arrive at emission factors.

2) A proposed methodology for determining India specific rail transport emission factors. This methodology considers specific steps from each of the different methods. It relies mostly on publicly available data so that it can be re-assessed periodically. It has also taken into consideration the difference in publicly available data. Data requirement, inherent challenges, assumptions, inclusions and exclusions pertinent to this methodology have also been discussed in detail in this paper.

3) A calculated emission factor, using the proposed methodology and currently available data in public domain, is described below:

1 Introduction

Railway locomotives generally are one of the three types: diesel, electric, or steam. Diesel locomotives generally use diesel engines in combination with an alternator or generator to produce the electricity required to power their traction motors. Electric locomotives are powered by electricity generated at stationary power plants as well as other sources. Steam locomotives are now generally used for localized operations, primarily as tourist attractions and their contribution to greenhouse gas emissions is comparatively small.

Green house gases are generated from all of the three types 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.

Currently, reporting companies use one of the three IPCC based approaches to estimate emissions from their rail transport i.e. Tier I, Tier II & Tier III.

The three tiers of estimation methodologies are variations of the same fundamental equation:

Emissions = Fuel Consumption X Emission Factor

Tier 1 Approach: In this approach, emissions are estimated using fuel-specific default emission factors, assuming that for each fuel type the total fuel is consumed by a single locomotive type.

Tier 2 Approach: This 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.

Tier 3 Approach: This 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 further stratified according to typical journey (e.g. freight, intercity, regional) and kilometers travelled by the train.

1.2 Limitations in adopting existing emission factors in the Indian scenario

Emission factor forms the basis of carbon inventorisation studies. It is that representative value that relates the quantity of green house gas emissions to the quantity of fuel used. Emission factors are generally derived from measurements made on a number of sources representative of a particular emission source. The more representative this emission factor is with respect to the geographic location & operations, the more accurate is the resultant emissions inventory.

A number of internationally accepted emission factor databases like the IPCC, DEFRA, EPA, Climate Registry are available for public use. These factors are derived based on a weighted average of aviation operations all over the world (IPCC) or specific countries like Europe (DEFRA) or USA (EPA). The major drawback with using these factors is that they are not specific to Indian operations. Operating conditions of Indian railways vary from other countries in terms of laws, regulations, policies, loading capacities, average distance traveled, types & efficiency of locomotives and climatic conditions. Clearly, there is a need for emission factors that accounts for India specific conditions for accurate emission accounting.

1.3 Objective of the Study

There is a general trend of increasing awareness in corporates towards identifying & reducing their emissions. A number of organizations are strengthening their GHG accounting by including scope 3, since it contributes to a large share of their overall emissions. The sphere of accounting of reporting companies in India have been expanding to include emissions from their business travel and material transport by rail. The challenge however, is to find India specific emission factors. Presently only international factors are available. India specific rail transport emission factors do not exist. Against this background, this study aims to arrive at India specific rail transport emission factors to aid the Indian corporate strengthen its GHG accounting process.

At the end of this investigation, emission factors for each vehicle type, specific to the Indian environment, as described below will be determined.

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

2 Methodologies commonly used to determine Rail emission factors

Broadly, all emissions factor calculators utilize the same methodology using the following input data:

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

Following are two methodologies used to calculate emissions from rail transport and their relevance.

2 Methodology

2.1 Method A: Using total fuel consumed by railway sector

This simple methodology 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. This fuel consumption is then converted to emissions using the fuels' calorific value & emission factors. Emissions are then allocated to passenger and freight transport on a weighted average basis using distance performed as shown below:

Step 1: Calculate overall CO_2 emissions from railway sector

$$\text{Overall emissions} = \begin{array}{c}(\text{Total diesel consumed X Calorific value X Density X Emission factor}) \\ + \\ (\text{Electricity usage X National grid emission factor})\end{array}$$

Step 2: Calculate Emission factor - CO2 emissions per passenger km and ton-km

$$\frac{\text{MT } CO_2 \text{ Emissions}}{\text{Passenger-km}} = \frac{\text{Overall emissions}}{\text{passenger km performed}}$$

$$\frac{\text{MT } CO_2 \text{ Emissions}}{\text{Ton-km}} = \frac{\text{Overall emissions}}{\text{freight ton-km performed}}$$

This method can be used when no information on fuel split between passenger and freight trains is available but the total energy consumption by rail traction is known.

2.2 Method B: EstimatingTotal Energy Consumption

This method involves determining emissions using the energy consumption of a particular route using the following equation:

Step 1: Calculate energy consumption

$$E' = \frac{(N_{stops} + 1)}{L} \frac{v_{max}}{2}^{2} + B_0 + B_1 . v_{ave} + B2\, v_{ave}^{2} + g \frac{Dh}{L}$$

Where:
E' : energy consumption in kJ/ton-km
N : number of intermediate stops
L : trip length (km)
v_{ave} : average speed (km/h)
v_{max} : maximum speed (km/h)
B_0 : constant equating to rolling resistance
B_1 : constant equating to friction resistance
B2 : constant equating to aerodynamic resistance
g : gravitational constant
Dh : change in height

Step 2: Conversion of energy consumption to emission factor

The equations below describe the method to convert energy consumption to emission factors:

- Electric trains

$$\frac{E' \times m \times L \times PSEFi}{10^6 \times P \times L}$$

- Diesel trains

$$\frac{E' \times m \times L \times FSEFi}{3600 \times P \times L}$$

Where:
E' is the energy consumption in kJ/ton-km
m is the mass of the train in tones
L is the trip length in km
PSEFi is the power specific emission factor in g/GJ
FSEFi is the fuel specific emission factor in g/kWh
P is the fraction of seats occupied

The calculation of aggregated emissions factors using Method 2 described above requires detailed information relating to every train journey within India. With the extensive rail network operating in India, the data availability is a concern.

3 Proposed method for Estimating India specific Rail Emission Factor

3.1 Methodology

The focus of this investigation is to determine the most suitable methodology to calculate emission factors using data available in public domain. The proposed methodology relies mostly on publicly available data, so that it can be re-assessed periodically. The proposed methodology has taken into consideration the difference in publicly available data between India and the international environment. It combines aspects from each of the two methods described earlier. This method uses country level railways annual data such as passenger kilometers, freight kilometers & load factor to arrive at emission factors. Average fuel consumption data has been used for calculations that are available in public domain.

This methodology will determine emission factors for domestic rail travel in India:

- Passenger Travel- Kg Co_2 / passenger-km

- Material Transport - Kg Co_2 / Ton-km

3.1.1 Passenger Transport

For passenger transport, the proposed methodology utilizes the yearly data published by the Indian railways. Each year, the Indian railways releases the statistical publication on various data pertaining to operation of the Indian railways. These publications provide detailed data on passenger travel, freight transport, electricity consumption, fuel consumption by class of services, etc.

The proposed methodology is dependent on the data provided by these publications. The numbers can be modified every year since the data is released annually by the Indian railways.

For passenger transport, there are two types of train travel used by the passengers, Sub-urban (Intercity) and Non Sub-urban (Long distance). For these type of transport, the number of passengers carried and average distance travelled by each passenger varies significantly. For example, in 2012-13, the average distance travelled by a passenger in the sub-urban type of train travel was 32.1 km while for the non-sub-urban the distance travelled was 234.6 km. Hence, it is necessary to have separate type of emission factors for sub-urban and non-sub-urban type of travel. Following is the methodology adopted for determining the emission factors for passenger transport:-

Step 1

Collecting fuel consumption data for passenger transport

1.Diesel Consumption (litres)………(a)

2.Electricity Consumption (kWh)………(b)

Data source: Annual Statistical Publication, Indian Railways

Step 2

Collecting emission factor for fuels

1.Diesel Emission Factor (kg CO_2/lit)………(c)

2.Electricity Emission Factor (kg CO_2/kWH)………(d)

Data source: IPCC Emission factor database and Central Electricity Authority (CEA)

Step 3

Deriving total emission from passenger transport

Total CO_2 Emissions =

{Diesel Consumption (a) x Diesel Emission Factor (c)} +

{Electricity Consumption (b) x Electricity Emission Factor (d)}

Step 4

Collecting passenger-km published by Indian Railways

1.Total Passenger-km

2.Suburban Passenger-km

3.Non suburban Passenger-km

4.Determining share of service for Suburban & Non suburban

Step 5

Determining emission factor by dividing emissions with passenger km

1.Emission factor (kg CO^2/pax-km) for non suburban =

(Emissions from non-suburban (kg CO_2)/ Non Suburban Passenger-km)

2.Emission factor (kg CO2/pax-km) for suburban =

(Emissions from suburban (kg CO_2)/ Suburban Passenger-km)

The only assumption in the methodology discussed above is that, the emissions from the passenger transport for sub-urban and non-sub-urban is in proportion to the share of passenger-km of sub-urban and non-sub-urban in total passenger-km. The assumption is made since the statistical publications do not provide any separate fuel consumption data for sub-urban and non-sub-urban.

3.1.2 Material Transport

The Indian railways currently transports more than 10 commodities. The major goods/commodities transported by the Indian railways is coal, iron and steel, cement and food grains. These commodities are transported in wagons and the companies that utilize the services are charged based on tonnage transported and kilometers travelled.
Annually, the Indian railways, provides detailed data such as fuel consumption, commodities transported in tonnage (total and classified), etc. with respect to goods transport. The proposed methodology is dependent on the data provided by such publications.

Following is the methodology adopted for determining the emission factors for passenger transport:-

Step 1

Collecting fuel consumption data for material transport
1.Diesel Consumption (litres)………(a)
2.Electricity Consumption (kWh)………(b)
Data source: Annual Statistical Publication, Indian Railways

Step 2

Collecting emission factor for fuels
1.Diesel Emission Factor (kg CO_2/lit)………(c)
2.Electricity Emission Factor (kg CO_2/kWH)………(d)
Data source: IPCC Emission factor database and Central Electricity Authority (CEA)

Step 3

Deriving total emission from material transport
Total CO_2 Emissions =
{Diesel Consumption (a) x Diesel Emission Factor (c)} +
{Electricity Consumption (b) x Electricity Emission Factor (d)}

Step 4

Collecting tonnage-km published by Indian Railways

Step 5

Determining emission factor by dividing total emissions with tonnage- km
1.Emission factor (kg CO_2/ton-km) =
(Emissions from Material transport (kg CO_2)/ Tons-km)

3.2 Emission Calculations by proposed methodology

Following is the emission calculation for passenger transport and material transport using the publicly available data.

3.2.1 Passenger Transport

Step 1: Collecting Fuel Consumption Data for Passenger Transport
Passenger Fuel Consumption (Total government Railways)

Fuel	Unit	2012-13
Diesel	Million kL	1.399902
Electricity	Million kWH	6120.085

Step 2: Collecting Fuel Emission factor

Fuel	Emission Factor	Unit	Source
Diesel	2.651	kg CO2/lit	C IPC
Electricity	0.82	kg CO2/kWh	CEA

Step 3: Deriving total emission from passenger transport

Fuel	Consumption (A)	Unit	Emission Factor (B)	Unit	CO_2 Emission (C = A x B)	Unit
Diesel	1.40	Million kL	2.651	kg CO_2/lit	3711.14	Million Kg CO_2
Electricity	6120.09	Million kWh	0.82	kg CO_2/kWh	5018.47	Million Kg CO_2
		Total (D)			8729.61	Million Kg CO_2

Step 4: Collecting Passenger Km & deriving share of emissions (Suburban & Non-Suburban)

	Unit	Non Suburban	Suburban
Passenger traveled	Million Nos.	3944	4477
Distance travelled	Km	241.5	32.5
Passenger km.	Million Pax-km	952476	145502.5
Share by Mode (E)	%	86.7	13.26
Emissions (Share) – D x E	Million Kg CO_2	7571.70	1157.91

Step 5: Determining emission factor by dividing emissions with passenger km

Particulars	Unit	Non Suburban	Suburban
Emissions	Million Kg CO_2	7571.70	1157.91
Passenger km.	Million Pax-km	952476	145502.5
Emission Factor	**kg CO_2/Pax-km**	**0.00794**	**0.00795**

3.2.2 Material Transport

Step 1: Collecting Fuel Consumption Data for Material Transport

Freight Fuel Consumption (Total government Railways)

Fuel	Unit	2012-13
Diesel	Million kL	1.016992
Electricity	Million kWh	4728.339

Step 2: Collecting Fuel Emission factor

Fuel	Emission Factor	Unit	Source
Diesel	2.651	kg CO2/lit	IPCC
Electricity	0.82	kg CO2/kWh	CEA

Step 3: Deriving total emission from passenger transport

Fuel	Consumption (A)	Unit	Emission Factor (B)	Unit	CO_2 Emission (C = A x B)	Unit
Diesel	1.016992	Million kL	2.651	kg CO_2/lit	2696.045	Million Kg CO_2
Electricity	4728.339	Million kWh	0.82	kg CO_2/kWh	3877.237	Million Kg CO_2
		Total (D)			**6573.283**	Million Kg CO_2

Step 4: Collecting Tonnage km for material transport

Particulars	Unit	2012-13
Tones Carried	Million Tones	1008.9
Net Tones Km	Million Tones km	691658

Step 5: Determining emission factor by dividing emissions with tonnage km

Particulars	Unit	2012-13
Emissions	Million Kg CO_2	6573.283
Tons- km.	Million Tons-km	691658
Emission Factor	**kg CO_2/Tons-km**	**0.009504**

INDIA GHG PROGRAM
Promoting profitable, sustainable and competitive businesses.

India GHG Program:

The India GHG Program acts as a 'Center of Excellence' by disseminating regional, sectoral and global best practices to create a culture of inventorisation and benchmarking of GHG emissions in India. To accomplish this, the primary objective of the India GHG Program will be to build institutional capabilities in Indian businesses and organizations. The India GHG Program brings together internationally recognized GHG accounting and measurement tools and methodologies that serve to create a key platform that facilitates national level benchmarking of GHG emissions and incentivises and rewards sustainable business initiatives. India GHG Program seeks a multi-stakeholder approach through effective representation of stakeholders (such as other industry associations, sector associations, ministries and government agencies, civil society organisations, and experts) in promoting a standardised approach to GHG accounting.

Indian businesses recognise the incentives of sustainable business practices but are challenged by a lack of uniformity in GHG measurement guidelines and a national benchmarking system. The lack of clear policy and regulatory directives, limited access to clean technology, absence of methods for footprinting data and inadequate institutional capacity act as constraints on the ability of middle managerial level business leaders to manage and measure GHG emissions. The India GHG Program will address the needs and expectations of industry in building capacity to mitigate economic, social and environmental risks while helping businesses remain profitable, competitive and sustainable.

The program offers a unique threefold proposition – expertise and recognition from three renowned organisations - WRI India, TERI and CII. It is a voluntary and flexible program influenced by and aligned to business expectations as compared to others that have a clearly defined agenda and methodology. It offers a value proposition to businesses in incorporating mitigation of carbon related risks into the overall business strategy – starting with capacity building, measurement and management of GHG Emissions, reporting and target setting, identifying reduction opportunities and ending with exploration of further avenues in carbon neutrality. The India GHG Program offers businesses public visibility and specialised incentives through improved efficiency and profitability. The India GHG Program also offers businesses opportunities to engage with industry, sectorial and regional peers on a single platform and access to policy makers and civil society to initiate dialog on actions businesses take and challenges they face in reducing GHG emissions.

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