सत्यमेव जयते
Ministry of Commerce & Industry
Government of India

PM GatiShakti
National Master Plan for Multi-Modal connectivity

INDIA LOGISTICS

Freight Greenhouse Gas Calculator

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

the Federal Republic of Germany

Freight Greenhouse Gas Calculator

Published by the

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Climate Friendly Freight Transport in India (Green Freight)
2nd Floor, B-5/2, Safdarjung Enclave, New Delhi-110029
Phone +91 11 49495353
SUID.India@giz.de
www.giz.de/india

As at
June 2022

Project Team

Dr Jivisha Joshi Gangopadhyay, Logistics Division, DPIIT

Ms Avni Mehta, Green Freight Project (GIZ India)

Mr Sharif Qamar (TERI)

Ms Palak Passi (TERI)

Mr Promit Mookherjee (TERI)

Ms Swati Nath (TERI)

Mr Varun Prakash Pandey (TERI)

Contributors (in alphabetical order)

Deepak Baindur (GIZ India), Gordon Telling (GIZ India), I V Rao (TERI), Pramod Rajendran (GIZ India), P Santosh Kumar (TERI), Shri Prakash (TERI), Tanya Mittal (GIZ India)

Design by:

The Energy and Resources Institute (TERI)

Registered Office:

The Energy and Resources Institute (TERI)
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail pmc@teri.res.in
Fax 24682144 or 24682145
Website www.teriin.org
India +91 • Delhi (0)11

Acknowledgements

We would like to extend our deepest gratitude to the individuals, organizations and experts for extending their support and providing their valuable inputs during the course of this project.

We acknowledge the support of Logistics Division, Department for Promotion of Industry and Internal Trade (DPIIT) for their constant support and insightful contribution at various stages of the study. In particular, our sincere thanks to Sh Amrit Lal Meena, Sh Pawan Kumar Agarwal, Dr Surendar Ahirwar, Sh Vikas Chaubey, and Smt. Shilpi Bishnoi for their key insights on the topic.

We would like to express our gratitude to the following organizations for sparing their valuable time and providing constructive inputs and data points that were helpful in developing the Calculator – Ministry of Railways, Centre for Railway Information System (CRIS), Freight Operations Information System (FOIS), Ministry of Ports Shipping and Waterways, Inland Waterways Authority of India (IWAI), Ministry of Civil Aviation (MoCA) and Directorate General of Civil Aviation (DGCA).

We would like to thank Mr B N Puri, Mr Vivek Chandran, and Mr Sudhir Gota for peer reviewing the methodology adopted for the project. We would also like to extend our appreciation to the Smart Freight Centre, The Netherlands, in particular Mr Marcus Lomax and Mr Mehul Khandelwal for peer reviewing the study.

About Logistics Division, Department for Promotion of Industry and Internal Trade (DPIIT):

The Logistics Division in the Department for Promotion of Industry and Internal Trade (DPIIT) is working towards integrated development of the logistics sector in the country, by way of policy changes, improvement in existing procedures, identification of bottlenecks and gaps and introduction of technology in logistics sector.

About GIZ:

As a service provider in the field of international cooperation for sustainable development and international education work, we are dedicated to shaping a future worth living around the world. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), GmbH in India is jointly working with partners for sustainable economic, ecological, and social development. The thematic areas of GIZ in India are: 1. Energy, 2. Environment, Climate Change and Biodiversity, 3. Sustainable Urban and Industrial Development and 4. Sustainable Economic Development

The Federal Ministry for Economic Cooperation and Development (BMZ), the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) as well as the Federal Ministry for Economic Affairs and Energy (BMWi) are the main commissioning parties of GIZ in India. Other clients include Indian public sector clients, the European Union and foundations.

About TERI:

TERI is an independent, multi-dimensional organization, with expertise in research, policy, consultancy and implementation in energy, environment, climate change and sustainability spheres. TERI seeks to usher transition to a cleaner and sustainable future through the conservation and efficient use of energy and other resources, and innovative ways of minimizing and reusing waste.

Amrit Lal Meena, IAS

Special Secretary, Logistics Division
Department for Promotion of Industry and Internal Trade (DPIIT)
Ministry of Commerce and Industry

Foreword

Transportation sector accounts for nearly 14% of India's total greenhouse gas emissions and freight transport accounts for over 40% of final energy use in the transport sector. The greenhouse gas emissions from the transport sector are growing at an alarming rate and urgent action is needed to deliver on the goals of the Hon'ble Prime Minister of achieving net-zero emissions by 2070.

Trucks are the largest energy consumer in this sector and is the fastest growing segment in freight. Rail retains a predominant role as a carrier of bulk materials, but it is suffering from stiff competition from other modes of transport. Hence, it becomes pertinent to move the goods on low carbon modes of transport as it is environment friendly as well as cost-effective.

Digital solutions have an integral role to play in transformation of the logistics sector in the country. The Freight GreenhouseGas (GHG) Calculator is one such intervention to create awareness and promote sustainability in the freight transport planning process and mode shift towards low-carbon modes of transport. It is a simple and easy-to-use tool for calculating and comparing total cost of transportation and GHG emissions between various modes of transport for a fixed Origin-Destination Pair. It will help the user undertake an informed modal choice based on total emissions and environmental costs estimates to advance green and sustainable logistics in India.

Such digital initiatives will not only promote multi-modality, improve logistics efficiency but most importantly induce a behavioural change towards making more sustainable choices in the country. This has the potential to boost India's ranking in the Logistics Performance Index. The GHG Calculator will be useful to the private sector along with the public sector to achieve the objective of sustainable freight mobility.

Table of Contents

Introduction

The Transport sector plays a key role in the economic development of a country. However, it generates a high direct demand for fuels with a significant contribution to greenhouse gas (GHG) emissions. In 2020, an estimated 40% of the final energy use in the Indian transport sector was related to freight transport.[1] With increased energy demand in tandem with economic progress, the need to develop sustainable transport practices becomes even more significant.

India has an expansive network of transport infrastructure, which has grown extensively in the last few decades. This growth has been witnessed in geographical expansion along with capacity augmentation of the existing network to meet the mobility and logistics needs of the country. Such rapid expansion has resulted in negative externalities such as air quality depletion, rising emissions, increased dependence on fossil fuels, and consequently health ailments and productivity loss.

The transport trajectory in India has been marked by a higher dependence on road transport (around 71%)[2] in the recent years shifting away from the rail network, which unfortunately, is the least energy efficient and environment-friendly mode compared to others. The social cost, consequently, in terms of environmental degradation is much higher.

Switching from a high carbon intensity mode to a lower one can have significant impacts on the overall emissions and energy consumption, given the transport infrastructure and network. Alternatively, other sustainable technologies and operational strategies are also available to reduce the associated emissions. Depending on the modal choice in addition to vehicle efficiency and technology, the transport sector provides an excellent opportunity to curtail the long-term impact of emissions with appropriate information and incentives.

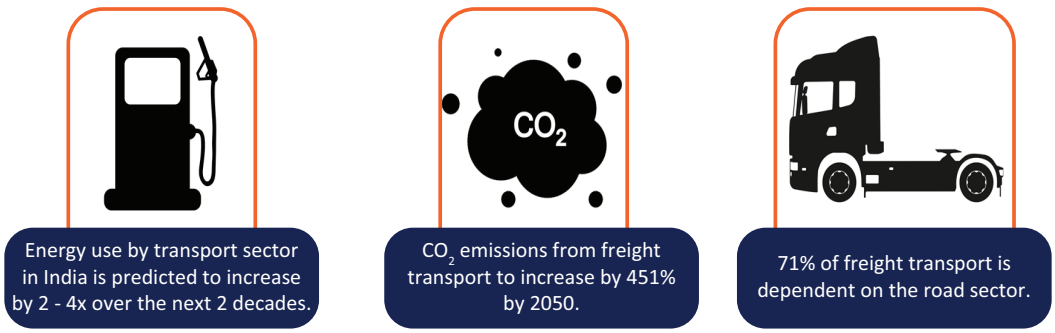


FIGURE 1: Transport emissions in India

Source: NTDPC Report[2],NITI Aayog, RMI & RMI India[3]

---

1 ITF (2021), "Decarbonising India's Transport System: Charting the Way Forward", International Transport Forum Policy Papers, No. 88, OECD Publishing, Paris.

2 NTDPC (National Transport Development Policy Committee). (2014). India Transport Report: Moving India to 2032. Planning Commission. New Delhi: Planning Commission, Government of India.

3 NITI Aayog, RMI and RMI India. (2021). Fast Tracking freight in India. Retrieved from https://rmi-india.org/insight/fast-tracking-freight-in-india-a-roadmap-for-clean-and-cost-effective-goods-transport

The web-based user-friendly *Freight GHG Calculator* enables users to make an informed and sustainable modal choice decision. The calculator helps users in estimating the emissions and costs on account of movement of freight through different transport modes. It calculates and compares movement by road, rail, inland waterways and air for different commodities, for both GHG emissions and total freight cost, including the environmental cost.

The Freight GHG Calculator quantifies and monetizes the environmental impact of freight transportation in India. The calculations are undertaken for the entirety of the transportation process where the emissions are quantified on a Well-to-Wheel (WTW) basis. The tool compares the emissions for freight transported by rail, road, inland waterways, and domestic air. It also considers the multi-modal transportation of goods.

Based on the database of emission factors and particular vehicle characteristics, emissions are estimated for the transportation of goods. The distances between origin and destination points are systematically sourced to allow for an accurate calculation of transport routes. Thus, the overall energy consumption and emissions are calculated and their monetary value estimated based on the social value of carbon to arrive at the total freight cost for the transportation service.

Objectives

Develop a user-friendly India-specific calculator to estimate GHG emissions and costs for freight transport for road, rail, inland water, and air modes of transport

Help government and non-government entities in the logistics sector to easily compare trade-offs involved in freight movement for various origin-destination (OD) points and reduce the overall carbon footprint from freight transport

Target Audience

The Freight GHG Calculator acts as a platform to quantify freight-related emissions and costs. The intended beneficiaries include but are not limited to the public sector and private sector (see Figure 2).

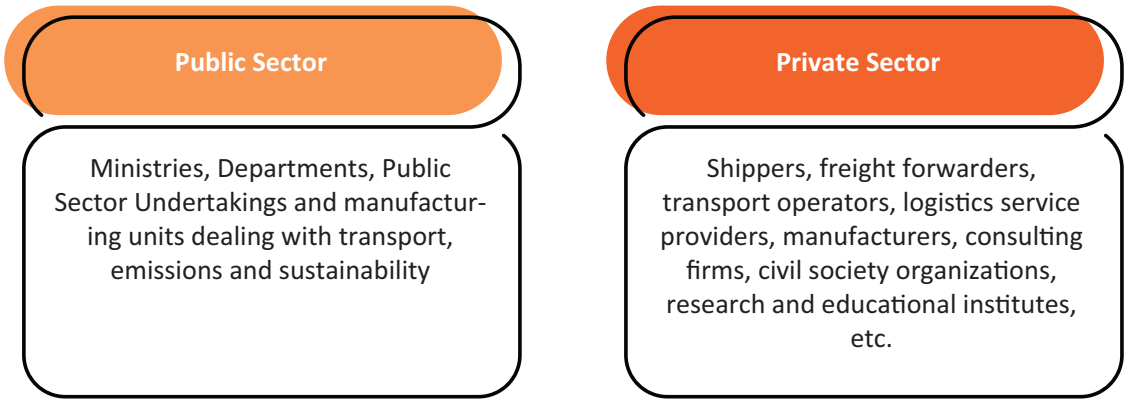


FIGURE 2: Target audience of the Freight GHG Calculator

Overall, the Freight GHG Calculator aims to induce an efficient decision-making process leading to reduced emissions and resource conservation with information dissemination at its core.

Apart from offering businesses visibility to their emission contribution and costs inclusive of environmental externalities, the Calculator can act as a customized tool for policymakers and GHG Program designers, which can be integrated in their research designs.

Benefits

One of its kind, the tool will allow calculation of complete transport chains across all modes of transport on the basis of scientific and neutral methodology.

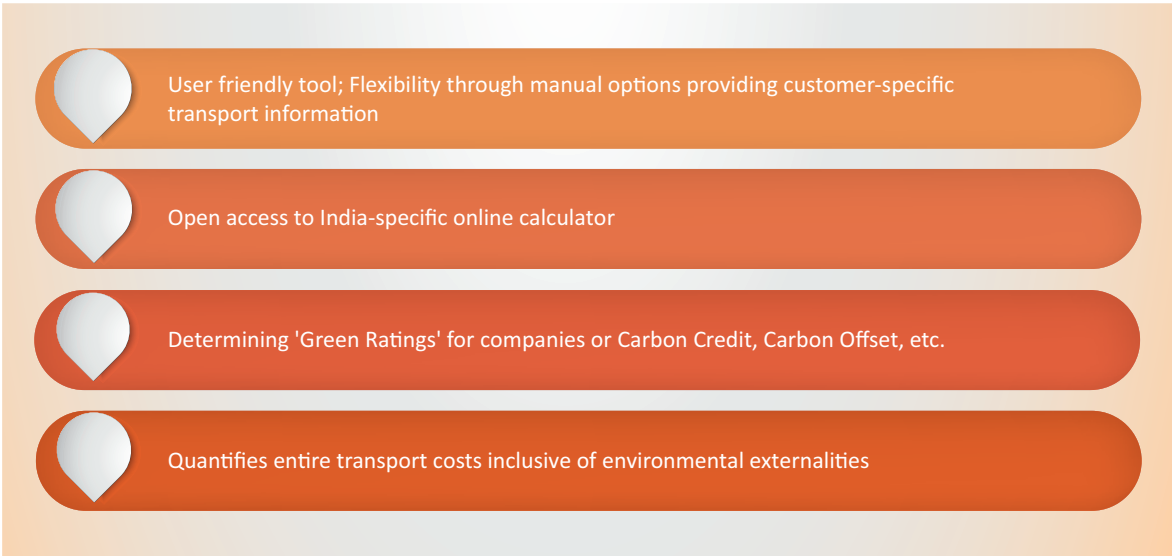


FIGURE 3: Expected benefits of the Freight GHG Calculator

Methodology

Basic Definitions and Calculation Rules

Some general terms and definitions used in this methodology report are explained below.

» **Freight tonne carried:** It is the number of tonnes of freight carried on a particular transport vehicle

» **Freight tonne-kilometres performed:** A metric tonne of freight carried in one kilometre. It is the sum of the products of tonnes of freight carried and the distance between the origin–destination points

» **Gross vehicle weight:** It is the total weight of the vehicle and the load certified by an authority as permissible

» **Fuel consumption:** It is the amount of fuel consumed by a vehicle to travel a given distance

» **Payload capacity:** It is the maximum mass of freight allowed usually expressed in mass-related parameter such as tonnes

» **Emission factor:** It is a coefficient, which relates the amount of GHG emissions to a specific business activity

» **Scheduled service (aviation):** Services provided by an airline for remuneration according to a published timetable and open to the general public for usage

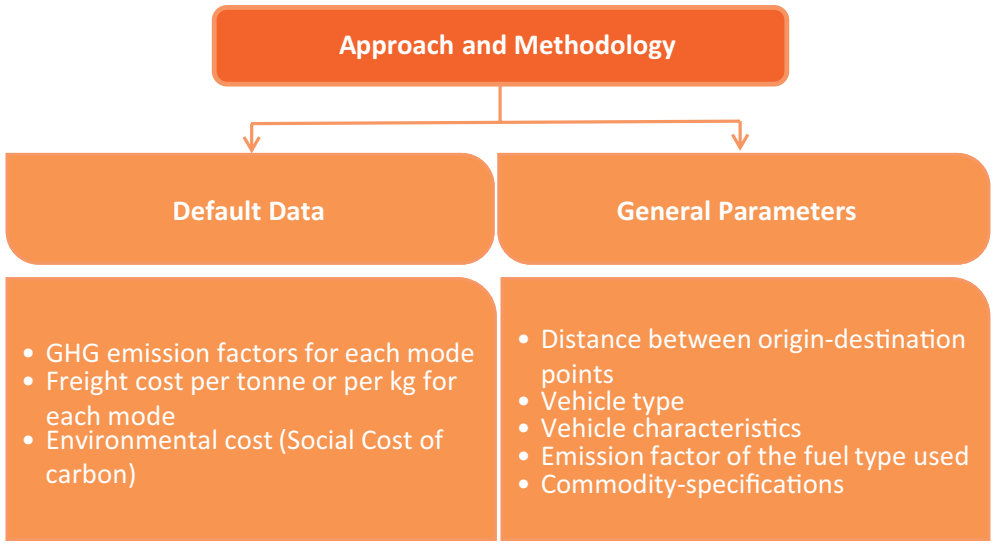


FIGURE 4: Calculation parameters and default data

It is possible to incorporate only some of the impact categories to make an effective comparison between individual transport modes on a quantitative basis. Accordingly, for the Freight GHG Calculator, the analysis had to be limited to a few but important parameters, which are based on impact relevance, data availability, and methodology fit.

A transport service results in **direct emissions** of GHGs depending on the vehicle type, fuel consumption, load and distance to be covered. However, certain emissions also occur owing to the production of fuels and energy, manufacturing of vehicles, and maintenance of the transportation network. Such **indirect emissions** are also to be accounted for when calculating the net effect of the freight transportation on GHG emissions.

Indirect emissions due to production and extraction of fuel, refining and transportation to the end user forms an important component of the emissions produced. On similar lines, for electrically-operated modes of transport such as trains, the generation of electric power is to be considered.

In this context, based on EWI and Standard EN 16258 “Methodology for calculation and declaration of energy consumption and greenhouse gas emissions of transport services”, indirect emissions are provided for in the Calculator by taking the emission factors on a **Well to Wheel** (WTW) basis.

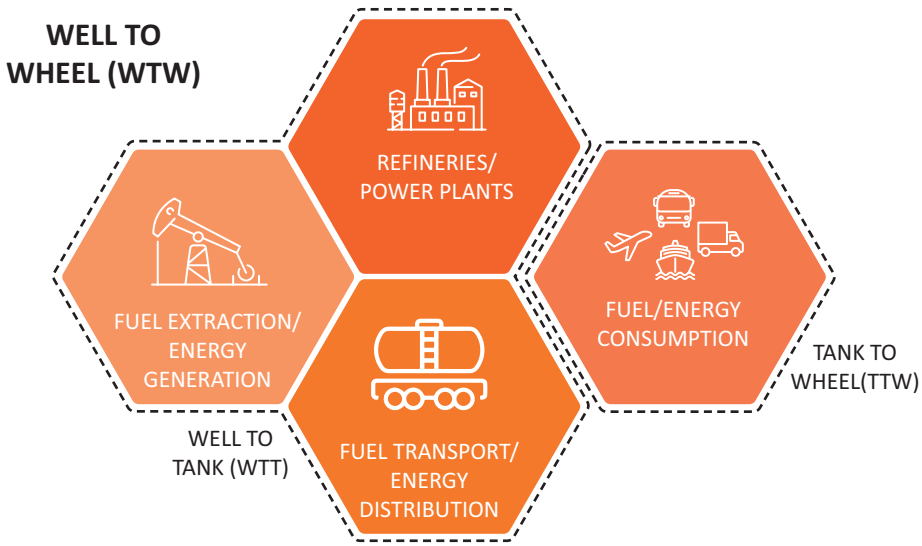


FIGURE 5: System boundaries

For the calculation of GHG emissions, CO_2e (carbon dioxide equivalent) is considered as carbon dioxide constitutes the largest share in the production of GHGs. It represents the impact of other pollutants on the environment using a conversion factor in CO_2, which would cause similar effects. Uniform emission factors are considered for each mode of transport and the transportation vehicle considered such that the emissions are calculated per unit of CO_2e.

CO_2e is calculated as follows (mass weighted):

$CO_2e = CO_2 + 25 * CH_4 + 298 * N_2O$

CH_4: Methane

N_2O: Nitrous oxide

Blueprint

This Calculator enables users to derive GHG emissions and freight costs by using the default options. However, the users are given an option to enter specific input values *manually* based on their experience to derive accurate GHG emissions and freight costs. The *input* and *output* parameters are discussed in detail in the following section. The general approach towards development of the Calculator is given below.

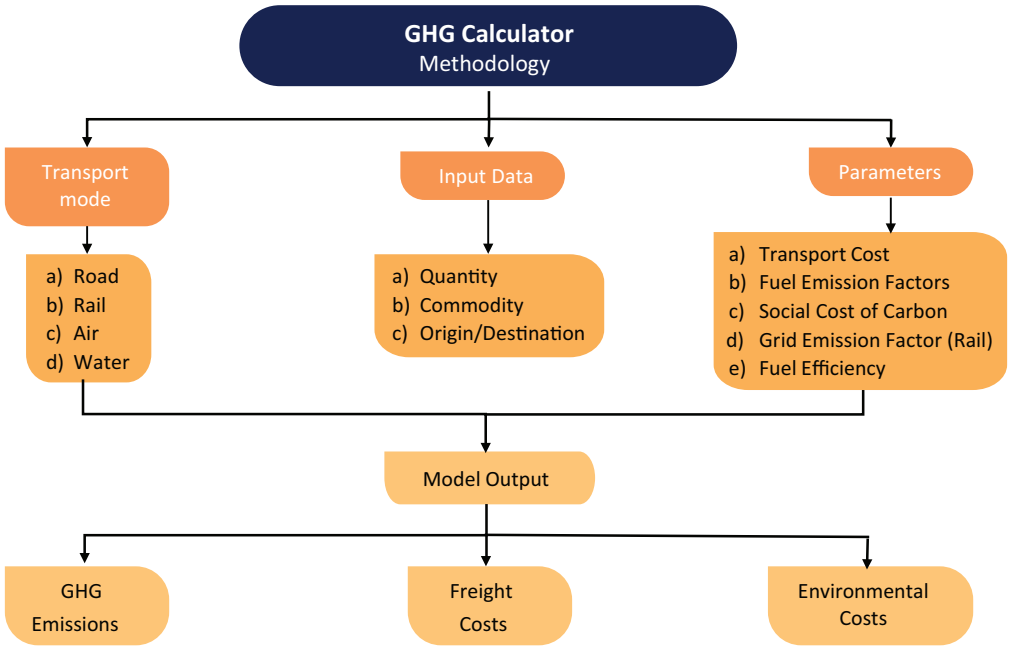


FIGURE 6: Freight GHG Calculator methodology

Input Parameters

The Calculator utilizes shipment, trip and cost inputs choices from the user for estimating the emissions and costs from freight movement. The data entered by the user is combined with fixed inputs such as emission factors to estimate GHG emissions, freight costs, and environmental costs.

Table 1 Input parameters

Mode	Input Parameters	Default Values with Manual Options	Fixed Parameters
Road	Shipment Information » Commodity type » Commodity weight and its unit Trip Information » Origin » Destination	» Truck size » Transport cost including truck rental cost and miscellaneous charges	» Emission factor for diesel » Fuel efficiency of trucks » Social cost of carbon
Rail	Shipment Information » Commodity type » Commodity weight and its unit Trip Information » Origin » Destination	Transport cost including » Terminal charges » First and last mile charges » Handling charges » Demurrage and wharfage » Additional concessions (%)	» Emission factor for diesel » Grid emission factor (electric rail) » Fuel efficiency » Social cost of carbon
Air	Shipment Information » Commodity type » Commodity weight and its unit Trip Information » Transport type – Belly cargo or Dedicated cargo » Origin » Destination	Transport cost including » Air tariff » Miscellaneous costs	» Emission factor for ATF » Fuel efficiency for freighter aircrafts » Freighter aircraft models and their payload capacity, cruising speed » Social cost of carbon
IWT	Shipment Information » Commodity type » Commodity weight and its unit Trip Information » Origin » Destination	Transport cost including » Water tariff » Miscellaneous costs	» Emission factor for LFO » Fuel efficiency » Social cost of carbon

Source: TERI

The basic principle involved in the calculation of emissions and costs are based on the weight of the shipment and the distance travelled (tonne-km). It is to be noted that the freight costs are dynamic in nature and would require regular updates.

The emission factors for fuel associated with distinct modes of transport are listed in the table on emission factors. For further details, please refer to the respective sections.

Table 2 Emission factors

Mode	Fuel Type	Emission Factor	Unit	Source
Road	Diesel	2.6444	$kgCO_2$ per litre of fuel	GHG Programme India for Road[4]
Rail	Diesel	2.64	$kgCO_2$ per litre fuel	GHG Programme India for Rail[4]
	Electric	0.82	$kgCO_2$ per kilowatt hour	GHG Programme India for Rail[4]
Aviation	ATF (Belly Cargo)	1.58	$kgCO_2$ per tonne-km	GHG Programme India for Air[4]
	ATF (Dedicated freighter)	3.88	$kgCO_2$ per kg fuel	EcoTransIT World Initiative[5]
IWT	LFO	3.151	$kgCO_2$ per litre of fuel	IPCC[6]

Source: GHG India Program,[4] EcoTransIT World Initiative,[5] IPCC Report[6]

Outputs

» **GHG emissions:** Mode-wise estimate of the total GHG emissions associated with the selected freight movement

» **Freight costs:** Mode-wise estimate of the total costs associated with selected freight movement

4 Details available at https://indiaghgp.org/

5 Environmental Methodology and Data Update. (2020). EcoTransIT World Initiative (EWI), Page 121

6 Details available at https://www.ics-shipping.org/wp-content/uploads/2020/08/draft-life-cycle-ghg-and-carbon-intensity-guidelines-for-maritime-fuels-1.pdf

» **Environmental costs:** Mode-wise estimate of the monetary cost to society from the GHG emissions, estimated based on the social cost of carbon for India. (86US$ per tonne of CO_2)[7]

The detailed methodology adopted in the Calculator to estimate the costs and emissions associated with different modes of freight transport is explained in the following sections.

Roadways

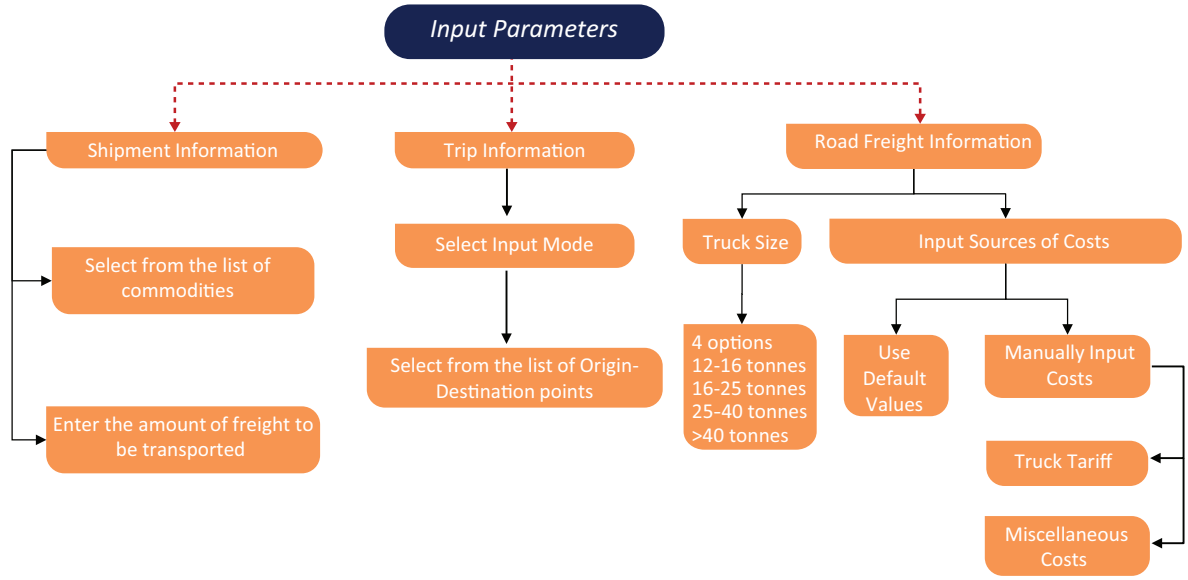


FIGURE 7: Input parameters for road freight

Estimation of Emissions for Roadways

Emissions from road freight are estimated based on the below principle:

Emission from road
= Transport distance by road*quantity of freight transported*vehicle emissions per net tonne-km

The emission per tonne-km is estimated based on the fuel efficiency of different trucks and the emission factor for diesel. The emissions are estimated for different truck sizes in order to reflect the difference in fuel efficiency for different truck sizes.

---

7 Social cost of carbon is defined as the quantifiable costs and benefits of emitting one additional tonne of CO_2, in monetary terms. The costs have been calculated for different countries, including India, by the Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. As per the study, the social cost of carbon for India is estimated to be US$86 per tonne of CO_2 as per the publication by Ricke, et al.

Table 3 Emission factor for roadways

Fuel Type	Emission Factor	Unit	Source[8]
Diesel	2.6444	$kgCO_2$ per litre of fuel	GHG Programme India for Road

Source: GHG Programme India for Road[8]

Table 4 Details of HDVs considered in the calculator

	Truck Size[8]	Average Payload (tonnes)	Mileage (km/lt)[9]	Diesel Consumption (lt/tkm)[10]	Emission Factor ($kgCO_2$/tkm)
	12–16 tonnes	10	5.10	0.019	0.05
	16–25 tonnes	14	4.63	0.015	0.04
	25–40 tonnes	25	3.03	0.014	0.04
	>40 tonnes	27	2.35	0.016	0.04
Source	GHG Programme India for Road	GHG Programme India for Road	Bureau of Energy Efficiency	TERI Analysis	TERI Analysis

Source: GHG Programme India for Road[8], TERI Analysis[10]

Similar to emissions, freight costs from road transport are also estimated based on the tonne-km travelled. Truck rental rates in India are dynamic and heterogeneous in nature. It varies with commodities, routes or ODs, regions, nature of relation between consigner/consignee and the trucking company, delivery time, etc.

Cost input: Since specific estimates would not be accurate, representative estimates of rates per tonne-km were obtained from a National Freight Index,[11] which was last updated in February 2020. While these rates may be slightly outdated, they are obtained based on sampling of about 950 lanes, which represent close to 70% of India's road freight traffic, and was deemed to be the most appropriate way of capturing a nationally representative rate.

8 Details available at https://indiaghgp.org/

9 Based on Phase 1 fuel efficiency norms for HDVs (Bureau of Energy Efficiency)

10 TERI Analysis

11 Details available at https://nationalfreightindex.co.in/

Table 5 Road freight rate (Rs/tkm)

Truck Size/Body type[8]	Type	Pan India	North	South	East	West	Pan India
Closed body							
32 ft MXL		2.46	2.12	1.94	1.95	3.27	2.46
32 ft SXL		4.99	4.03	4.34	7.06	5.19	4.99
Container		3.65	4.7	4.59	7.48	5.68	3.09
Open body							
12–16 tonnes	6 tyre	2.49	2.49	2.17	3.71	3.71	2.98
16–25 tonnes	10 tyre	1.81	1.81	1.98	3.57	2.99	2.41
	12 tyre	2.16	2.16	1.77	2.88	2.45	2.21
25–40 tonnes	14 tyre	2	2	1.62	2.46	2.38	2.2
>40 tonnes	18 tyre	2	2	1.62	2.46	2.38	2.2
	22 tyre	2	2	1.62	2.46	2.38	2.2

MXL: Muti-axel; SXL: Single-axel
Source: National Freight Index (Rivigo)[11]

However, these representative unit costs may not represent exact location and situation-specific estimates. Hence, the user is provided the option to directly input costs, if available, in Rs per tonne-km.

Limitations and Assumptions for Roadways

» The cost estimates for road freight are based on representative unit costs for freight movement in India and may not to be an exact location-specific estimate. The user is provided the option to directly input costs, if available.

» Truck rental rates in India are dynamic and heterogeneous in nature. It varies with commodities, routes or ODs, regions, nature of relation between consigner/consignee and the trucking company, delivery time, etc. The Calculator uses the National Freight Index, which was last updated in February 2020.

Railways

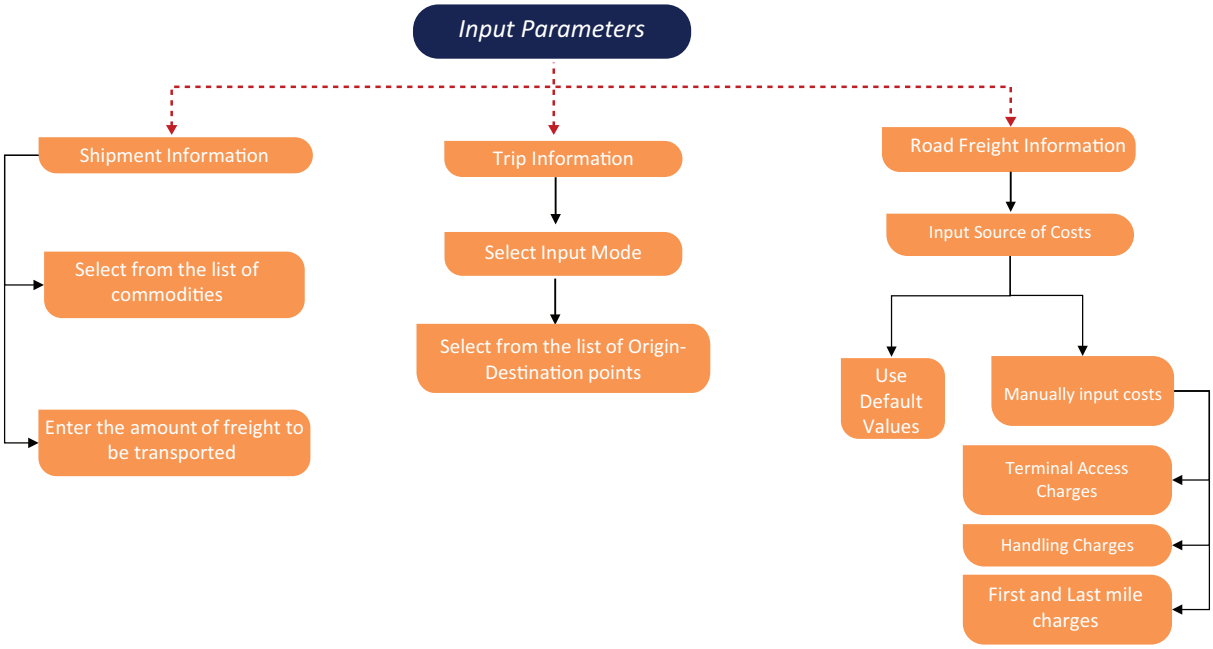


FIGURE 8: Input parameters for rail freight

Estimation of Emissions for Railways

Emissions from rail freight are also based on tonne-km covered:

Emission from rail
=Transport distance by rail*quantity of freight transported
****vehicle/rake emissions per net tonne-km***

The emission factors from rail were estimated to account for the proportion of rail freight that is carried by diesel and electric traction in India. Fuel use from the Indian Railways Annual Statistical Statement (2018–19)[12] was used to estimate the emissions from diesel and electric traction.

The estimated emissions were converted to tonne-km based on the tonne-km of freight moved by diesel and electric traction to obtain an overall emission factor for freight movement by railways. For electric traction, the grid emission factor obtained from the Central Electricity Authority, were applied. This method is similar to the method followed by India GHG programme publications.[13]

---

12 Details available at https://indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf/2021/AnnualSS_Book.pdf (page 338)

13 Details available at https://indiaghgp.org/

Table 6 Emission factors for Railways

Fuel Type	Emission Factors	Unit	Source[13]
Diesel	2.64	$kgCO_2$ per litre fuel	GHG Programme India for Rail
Electric	0.82	$kgCO_2$ per kilowatt hour	GHG Programme India for Rail

Costs from rail freight were broken up into different components to incorporate the additional multi-modal aspects associated with movement by rail. The components are described below:

Table 7 Cost components associated with rail transportation

Cost component	Description	Data source	Comments
Rail tariff	The per tonne rate charged by Indian Railways for moving freight. The rates differ by commodity type and are telescopic, so rate is lower as the distance increases	FOIS[14]	Directly applied based on the distance and weight being carried
Terminal charges	Access charges for using terminals	Indian Railways	Not applied on commodities, assumed to originate from private sidings. Exempted for automobile transportation Can be directly entered by user as well
First and last-mile charges	Cost of transport goods to and from the rail terminal to origin and destination points	Based on stakeholder interactions	Not applied on commodities assumed to originate from private sidings. Exempt for automobiles Can be directly entered by user as well
Handling charges	Cost of loading and unloading goods at terminals	Based on stakeholder interactions	Can be directly entered by user as well

Source: TERI

[14] Details available at https://www.fois.indianrail.gov.in/FOISWebPortal/FWP_FrgtRates

Limitations and Assumptions for Railways

» The handling charges and first- and last-mile costs for rail are taken based on representative estimates and may not represent location-specific charges. The user is provided with the option to directly input costs, if available.

» To arrive at emissions from the railways, emission factor of diesel and electricity have been taken based on the proportion of goods moved by diesel traction and electric tractions as per Indian Railways' Annual Statistical Summary.

Aviation

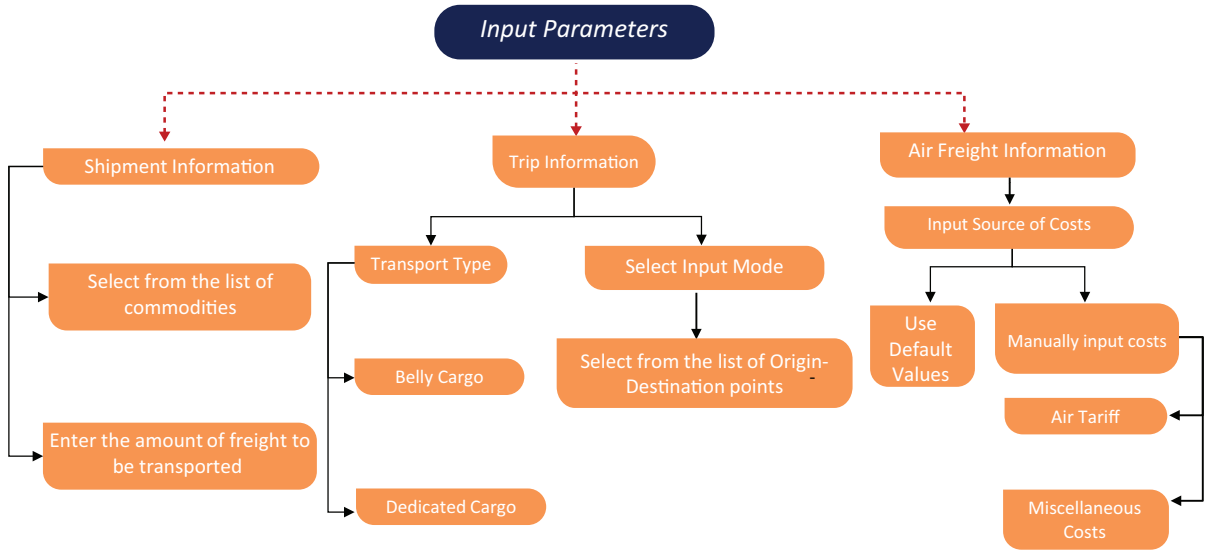


FIGURE 9: Input parameters for aviation

Estimation of Emissions for Aviation

Emissions from air freight are estimated based on the below principle:

Emissions from air
= Transport distance by air * Quantity of freight transported
**** Aircraft emissions per net tonne-km***

The emission per-tonne km is estimated based on the fuel efficiency of different aircrafts and the emission factor for aviation turbine fuel. The emissions are estimated for different aircraft types in order to reflect the difference in fuel efficiency for different aircrafts.

Table 8 Estimation of aircraft-specific emission factors

	Air Model[15]	Fuel Consumption (kg/hr)[16]	Cruising Speed (km/hr)[17]	Payload (t)[18]	Fuel Consumption (lt/tkm)	Emission Factor ($kgCO_2$/tkm)
	B757-200	3320	850	36	0.136	0.421
	B737-700	2420	828	20.00	0.183	0.567
	B737-800	2530	842	23.9	0.157	0.488
	Q400	900	667	8.50	0.198	0.616
	A340-300	6500	871	50	0.186	0.579
		Average				0.534
Source	Handbook on Civil Aviation Statistics, MoSPI	Aviation and Aircraft articles	Airline Websites	Airbus Manual, Airline Websites	TERI Analysis	TERI Analysis

Source: MoSPI,[15] Aviation and Aircraft articles,[16,17] Airline websites[18]

The emissions for goods transported as belly cargo are estimated from the India GHG Programme, calculated as CO_2 equivalent emissions per kg km.

Table 9 Emission factors for aviation

Fuel Type	Transport Type	Emission Factor	Unit	Source[19,20]
ATF	Belly cargo	1.58[19]	$kgCO_2$ per tonne km	GHG Programme India for Air
ATF	Dedicated freighter	3.88[20]	$kgCO_2$ per kg fuel	EcoTransIT World Initiative

Source: India GHG Programme[19] and Eco TransIT Methodology Report[20]

15 Handbook on Civil Aviation Statistics,2019-20, Airline Websites and http://mospi.nic.in/sites/default/files/reports_and_publication/cso_research_and_publication_unit/Infrastructure_Statistics/infra_stat_2010/5.ch_Air%20_transport.pdf, Page 190

16 Details available at https://alliknowaviation.com/2019/12/14/fuel-consumption-aircraft/,https://www.airlines inform.com/commercial-aircraft/boeing-737-900.html

17 Details available at https://www.rocketroute.com/aircraft/, https://modernairliners.com/boeing-737/boeing-737-max/

18 Airbus Manual and Airline Websites; https://www.airindia.in/fleet-details.htm, https://www.fly-car.de/local/media/formulare/airbusindustries.pdf,https://www.business-standard.com/article/news-ani/spicejet-converts-three-q400-passenger-aircraft-into-freighters-120052800357_1.html

19 India Specific Air Transport Emission Factors for Passenger Travel and Material Transport For Stakeholder Consultation, India GHG Program,2015, Published By: India GHG Program, WRI India, Mumbai, Page 15

20 Environmental Methodology and Data Update 2020, EcoTransIT World Initiative (EWI), Page 121

Similar to emissions, freight costs from aviation are also estimated based on the per unit weight unit distance travelled. The costs of transportation vary with the weight of the commodity (kg), type of commodity (general and special) as well as the OD points.

Freight costs in the aviation sector are calculated in terms of inbound charges and outbound charges depending on the OD points. Furthermore, the charges are broken down into its components – Terminal Storage Processing Charges (TSP), Cargo Handling Charges (CHC), and other miscellaneous charges. All of the above components vary with the origin and destination airports.

Table 10 Cost components associated with aviation

Cost component	Description	Data Source[21]	Comments
Terminal Storage Processing Charges (TSP)	The per kg rate charged for services employed at the terminal for moving freight	AERA Tariff Orders	The rates differ by commodity type Directly applied based on the O/D and weight being carried
Cargo Handling Charges (CHC)	The per kg rate charged for handling (loading and unloading) the air freight	AERA Tariff Orders	The rates differ by commodity type Directly applied based on the O/D and weight being carried
Miscellaneous Charges	The per kg rate including other charges such as palletization, de-palletization, X-Ray screening charges	AERA Tariff Orders	Can be directly entered by user as well

Source: TERI

To arrive at an average value in Rs/kg estimate, six major airports based on their freight share are considered. For each of the airport, TSP as well as CHC charges are obtained from the tariff orders separately for General Cargo and Special Cargo. Additionally, miscellaneous charges are calculated for each of the airports – considering both inbound and outbound points.

Thus, for each of the type of commodity considered, i.e., General Cargo and Special Cargo, Inbound TSP, Inbound CHC and Inbound Miscellaneous charges are calculated for the destination points. On similar lines, Outbound TSP, Outbound CHC and Outbound Miscellaneous charges are calculated for the origin points.

Unit Costs =Inbound Charges (TSP+CHC+Miscellaneous Charges)+ Oubound Charges (TSP+CHC+Miscellaneous Charges)

[21] Details available at http://www.aera.gov.in/aera/content/tariff.html

*Inbound charges = Charges levied at the destination point

**Outbound charges = Charges levied at the origin point

An average value in Rs/kg is then estimated for the airports for each of the commodity type considered.

$$\textit{Freight Cost}\left(\frac{\textit{Rs}}{\textit{kg km}}\right) = \frac{\textit{Unit Costs}\left(\frac{\textit{Rs}}{\textit{kg}}\right)}{\textit{Distance between O D points (km)}}$$

Based on the above formula, a matrix is developed so as to calculate the charges for freight transportation between the OD points selected for both the commodity types factoring in the distance between the airports.

Freight cost in Rs/kg-km is then estimated for each OD pair considered in the calculations to arrive at a representative average cost for General Cargo and Special Cargo.

Table 11 Average cost calculations for General Cargo and Special Cargo

Parameter	General Cargo	Special Cargo
Average cost (Rs/kg)	6.29	8.17
Average cost (Rs/kg-km)	0.014	0.018

Source: TERI Analysis[22,23]

Limitations and Assumptions for Aviation

While developing the Calculator, the team came across certain unavoidable limitations. These have been listed below:

» The cost estimates for air freight are based on estimated unit costs for freight movement in India and may not be an exact location-specific estimate. The user is provided the option to directly input costs, if available.

» The emission factor for belly cargo has been calculated from the data available for domestic passenger carriers. The calculation is not applicable for international cargo movement. GHG emission factor for belly cargo has been sourced from the India GHG Programme. The calculations undertaken in the report are based on the domestic numbers to arrive at an emission factor for ATF in kg CO_2/tonne-km.

22 Based on AERA Tariff Orders. Details available at http://www.aera.gov.in/aera/content/tariff.html

23 The above data is verified from the following report - Fast Tracking Freight in India – NITI Aayog, RMI and RMI India, 2021 (Cited from "Air Freight: A Market Study with Implications for Landlocked Countries," World Bank, 2009), which exhibits the freight rate for aviation as INR 18/tonne km. (Page 31)

» Unscheduled flights are not considered in the Calculator as they account for only a small proportion of the market share.

» For dedicated cargo carriers, emissions are estimated per tonne-km based on fuel consumption, speed and the payload capacity of the selected aircraft models.

Inland Waterways

For the calculation for transportation of freight cost and emissions by inland waterways, the Calculator uses shipment information, i.e., commodity type and weight; trip information, i.e., origin and destination pair; and cost parameters, i.e., water tariff and miscellaneous costs. The data entered by the user is combined with fixed inputs such as emission factors to estimate GHG emissions, freight costs, and environmental costs.

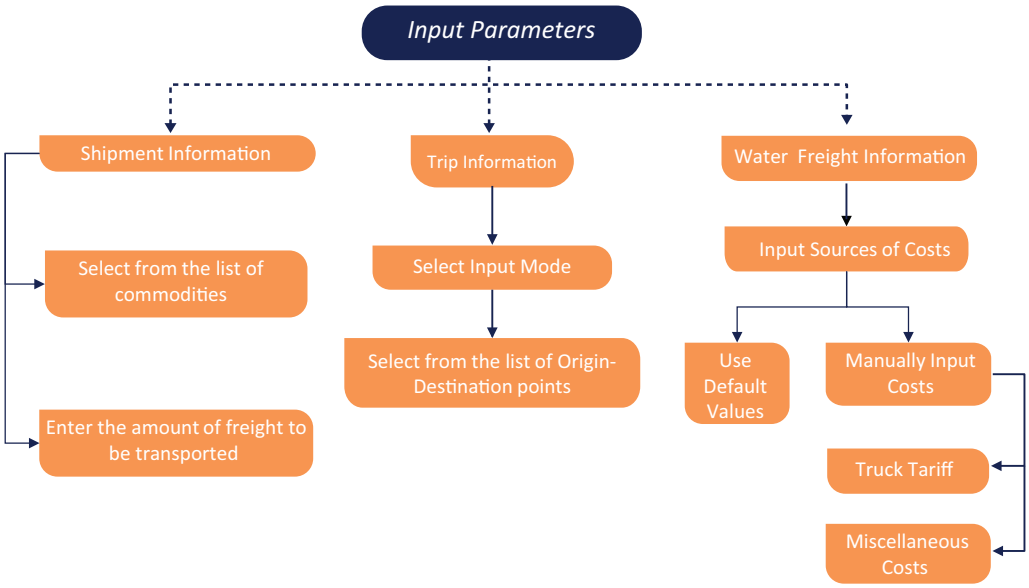


FIGURE 10: Input parameters for IWT

Estimation of Emissions for IWT

Emission from IWT
=Transport distance by water
****quantity of freight transported in tonnes*emissions per tonne-km***

As per the primary survey of the shippers, it is estimated that one litre of fuel can move 163.175 tonne-km freight by IWT. The following numerical inferences were drawn with respect to the emissions-

Table 12 Emission factor for IWT

Fuel Type	Emission Factors ($kgCO_2$/litre of fuel)	Fuel Consumption (Litre/tkm)	Emission Factor ($kgCO_2$/tkm)
LFO	3.151	0.006457	0.0203468

Source: IPCC[24] and TERI Analysis

For the total transportation costs from IWT, commodity-specific base freight rate (Rs per tonne-km) and miscellaneous cost (Rs per tonne-km) has been considered.

Table 13 Cost components associated with IWT

Cost Component	Description	Data Source	Comments
Water tariff	Per tonne-km rate charged by IWT for moving freight	IWAI	Directly applied based on the distance and weight being carried Can be entered by the user as well
Miscellaneous charges	Inclusive of terminal, insurance, and operational charges	IWAI	Included in the cost calculations Can be entered by user as well

IWT Freight Rate

Table 14 Commodity-specific base freight rate, insurance and terminal handling charges (Rs/tkm)

Commodity	Base Freight Rate	Insurance (Rs/tkm) (Rs/tkm)	Terminal Handling Rate (per Handling) (Rs/tkm)
Coal	1.83	0.01	0.06246
Fly Ash	1.83	0.01	0.06246
Sulphur	1.83	0.01	0.06246
Rock Phosphate	1.83	0.01	0.06246
Construction Material	1.8	0.03	0.0545
Food and Food Stuff	3.15	0.36	0.096
Goods	3.15	0.36	0.096
Container	3.94	0.72	0.16774
Automobile	6.62	0.6	0.03699
Liquid Bulk	1.58	0.01	0.0487
LAG	1.58	0.01	0.0487
Phosphoric Acid	1.58	0.01	0.0487

Source: IWT Sector Development Strategy and Business Development Study for Capacity Augmentation of National Waterway 1 from Haldia to Allahabad Volume I: Report Part A[25]

[24] Details available at https://www.ics-shipping.org/wp-content/uploads/2020/08/draft-life-cycle-ghg-and-carbon-intensity-guidelines-for-maritime-fuels-1.pdf

[25] Details available at http://iwai.nic.in/sites/default/files/6707675769NW%201%20%28JMVP%29%20Market%20Dev%20Analysis%20Report%20HPC.pdf

Miscellaneous Costs

Table 15 Overall miscellaneous cost (Rs/tkm)

Cost Parameters	Cost per NTKM
Fuel and Oil	0.22
Labour and Staff	0.01
Terminal	0.31
Repair and Maintenance	0.02
Overhead	0.02
Capital	0.05
Tolls/User Charges	0.05
Total Cost	**0.68**

Source: IWT Sector Development Strategy and Business Development Study for Capacity Augmentation of National Waterway 1 from Haldia to Allahabad Volume I: Report Part A[24]

$$\textit{Total Miscellaneous cost}\ \left(\frac{Rs}{tkm}\right)$$

$$= Insurance + Terminal\ Handling\ Rate + [\ Fuel\ and\ Oil + Labour\ and\ Staff + Terminal + Repair\ and\ Maintenance + Overhead\ Capital + Tolls\ /\ User\ Charges\ ]$$

$$\textit{Total Freight Cost}\ \left(\frac{Rs}{tkm}\right)$$

$$= (Commodity\text{-}Specific\ Base\ Freight\ Rate + Miscellaneous\ Cost)$$

Table 16 presents the overall commodity-specific cost used in the Calculator. The user is also given the option to input their costs manually in the Calculator, if available.

Table 16 Commodity-specific freight costs for IWT

Commodity	Total Miscellaneous Cost (Rs/tkm)	Total Freight Cost (Rs/tkm)
Coal	0.76	2.59
Fly Ash	0.76	2.59
Sulphur	0.76	2.59
Rock Phosphate	0.76	2.59
Construction Material	0.77	2.57
Food and Food Stuff	1.14	4.29
Goods	1.14	4.29
Container	1.57	5.51
Automobile	1.32	7.94
Liquid Bulk	0.74	2.32
LAG	0.74	2.32
Phosphoric Acid	0.74	2.32

Source: IWAI

Limitations and Assumptions for IWT

» The application programming interface (API) to calculate distance for inland water transport is currently not available and therefore fixed ODs and respective distances have been taken. The ODs and distances for the operational National Waterways are based on the information publicly available.

» For calculations, Rs. 0.68 per tkm has been added to the miscellaneous cost for all commodities.

References

Directorate General of Civil Aviation. (2019). *Handbook on Civil Aviation Statistics*.

EcoTransIT World Initiative (EWI). (2020). *Environmental Methodology and Data Update 2020*.

HPC and UNICONSULT. (2016). *IWT Sector Development Strategy and Business Development Study for Capacity Augmentation of National Waterway 1 from Haldia to Allahabad Volume I: Report Part A*. Retrieved from http://iwai.nic.in/sites/default/files/6707675769NW%201%20%28JMVP%29%20Market%20Dev%20Analysis%20Report%20HPC.pdf

International Transport Forum, ITF. (2021). *Decarbonising India's Transport System: Charting the Way Forward*. Paris: OECD Publishing.

Ministry of Railways, Government of India. (2021). *Indian Railways Annual Statistical Statements 2019-20*. Retrieved from https://indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf/2021/AnnualSS_Book.pdf

National Greenhouse Gas Inventories Programme IPCC (2008). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Japan: Institute for Global Environmental Strategies.

NITI Aayog, RMI and RMI India. (2021). *Fast Tracking freight in India*. Retrieved from https://rmi-india.org/insight/fast-tracking-freight-in-india-a-roadmap-for-clean-and-cost-effective-goods-transport.

NTDPC (National Transport Development Policy Committee). (2014). *India Transport Report: Moving India to 2032*. New Delhi: Planning Commission, Government of India.

Ricke et al. (2018). *Country-level Social Cost of Carbon* (p. 895–900). Nature Climate Change, Volume 8. Retrieved from https://www3.nd.edu/~nmark/Climate/s41558-018-0282-y.pdf

RITES, Gurgaon. (2014). *Integrated National Waterways Transportation Grid Study (Stage 1 of Phase II), Final Report* (p. v). New Delhi: Inland Waterways Authority of India. Retrieved from http://iwai.nic.in/sites/default/files/INT_NAT_WAT_TRA_GRI_STU_Part1_3-26947128.pdf

Shipping Zero Emission Project. (2020). *Roadmap to Zero Emission from International Shipping* (p. 60). Retrieved from https://www.mlit.go.jp/common/001354314.pdf

The India GHG Program. (2015). *India Specific Air Transport Emission Factors for Passenger Travel and Material Transport*. Mumbai: India GHG Program, WRI India.

The India GHG Program. (2015). *India Specific Rail Transport Emission Factors for Passenger Travel and Material Transport*. Mumbai: India GHG Program, WRI India. Retrieved from https://indiaghgp.org/sites/default/files/Rail%20Transport%20Emission.pdf

The India GHG Program. (2015). *India Specific Road Transport Emission Factors for Passenger Travel and Material Transport*. Mumbai: India GHG Program, WRI India. Retrieved from https://shaktifoundation.in/wp-content/uploads/2017/06/WRI-2015-India-Specific-Road-Transport-Emission-Factors.pdf

Annexures

Methodology and Formula Details

Road

Inputs	Parameters	Factors Considered	Source	Results (Formula used)
Distance		-	Google Maps	Shortest distance in km
Commodity	Origin - Destination Points	Based on Maximum Movement between OD	-	-
Tonne-km		1. Distance 2. Quantity (Tonne)	-	TKM by Road = Distance by road x Quantity (in tonnes)
Emission Factor		1. Truck Size 2. Fuel consumption ($kgCO_2/km$)	» GHG Programme India for Road » TERI Analysis	Road Emissions in tCO_2 = Emission Factor (based on truck size) x TKM by Road
Freight Cost		Truck size Rate per tonne-km Distance travelled by road	National Freight Index (*Represents close to 70% of India's road freight traffic*)	» Truck Tariff = Rate per tonne km x TKM by road » Total Cost = Truck Tariff + Miscellaneous Charges
Environmental Cost		Social Cost of carbon	Country-level Social Cost of Carbon, Nature Climate Change, Vol 8, October 2018, 895–900	SCC for road = Emission by road (tCO_2) x $US86 per tCO_2

Rail

Inputs	Parameters	Factors Considered	Source	Results (Formula used)
Distance		-	FOIS – Freight Calculator	Shortest distance in km
Commodity	Origin - Destination Points	Based on Maximum Movement between OD	-	-
Tonne-km		1. Distance 2. Quantity (Tonne)	-	TKM by Rail = Distance by rail x Quantity (in tonnes)
Emission Factor		1. Fuel consumption – Diesel (CO_2 emission factor) and Electric (grid emission factor) 2. Tonnage km	» GHG Programme India for Rail » Indian Railways – Annual Statistical Statement Report	Rail Emissions in tCO_2 = Emission Factor x TKM by Rail
Freight Cost		1. Commodity-wise rate per tonne 2. Quantity (tonne) 3. Distance travelled by rail	FOIS – Commodity-wise Freight rate	» Rail Tariff = Rate per tonne depending on the distance travelled x Quantity (in tonnes) » Total Cost = Rail tariff + Development Charges + GST + Terminal charges + First- and Last-mile charges + Handling Charges
Environmental Cost		Social Cost of carbon	Country-level Social Cost of Carbon, Nature Climate Change, Vol 8, October 2018, 895–900	» SCC for rail = Emission by rail (tCO_2) x $US86 per tCO_2

Aviation

Parameter	Sub heading	Units	Formula	Source	Remarks
Distance	O/D	km	1 mile = 0.869 nm 1 nm = 1.852 km	Airport distance Calculator	Great Circle Distance
Aircraft	Airline and Aircraft type		-	Handbook on Civil Aviation Statistics Airline Websites	
	Cargo Capacity	Tonnes	1kg= 0.00110231 tonnes	Airbus Manual Air India Website	-
	Fuel Consumption	kg fuel/hr	Converted to l/hr 1 kg of ATF fuel = 1.25l of ATF fuel	https://alliknowaviation.com/2019/12/14/fuel-consumption-aircraft/	-
	Cruising speed	km/hr		https://www.rocketroute.com/aircraft/ Google search	-
Commodity type	Quantity	kg	-	-	-
	Tariff	Rs/kg km		AERA Tariff Orders Fast Tracking freight in India – NITI Aayog, RMI and RMI India,2021 ("Air Freight: A Market Study with Implications for Landlocked Countries," World Bank, 2009)	TSP + CHC + Misc. charges

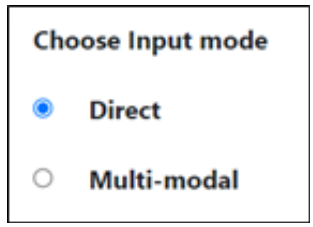
Parameter	Sub heading	Units	Formula	Source	Remarks
Emissions	Emission factor	kg CO_2/tonne-km; converted to kg CO_2/kg km		GHG India Programme Aviation Report	Belly Cargo
	Emission factor	kg CO_2/ kg fuel	Estimated as kg CO_2/ tonne-km	Environmental Methodology and Data Update,2020 Eco TransIT Report	Dedicated freighter
Freight Cost		Rs	Tariff = Rate per kg km x Quantity transported (kg) x Distance between O/D points (km)		Tariff rate depends on the Airport-to-Airport distance
			Total Cost = Tariff (TSP +CHC + Miscellaneous charges) + GST		
Environmental Cost	Social Cost of Carbon	Rs	SCC = Emission by air (tCO_2) x $US86 per tCO_2	Country-level Social Cost of Carbon, Nature Climate Change, Vol 8	

Inland Waterways

Inputs	Parameters	Factors Considered	Source	Results (Formula used)
Distance	-	National Waterways 1,2,3	IWAI	Navigable distance in km
Commodity	National waterway wise Origin - Destination Points	Based on Maximum Movement between OD pairs	IWAI	-
Tonne-km	-	1. Distance (in km) 2. Quantity (tonne)	-	TKM by IWT = Distance by water x Quantity (in tonnes)
Emissions	-	1. Fuel consumption –LFO (CO_2 emission factor) 2. Tonnage km	» IPCC Guidelines for National Greenhouse Gas Inventories, 2006 » EEDI Calculation Guidelines » Primary Survey of Shippers	IWT Emissions in tCO_2 = Emission Factor x TKM by IWT
Freight Cost	-	1. Rate per tonne-km 2. Distance travelled by water	IWAI DPRs	IWT Freight Tariff = Rate per tonne-km (inclusive of miscellaneous cost) x TKM by water
Environmental Cost	Rail	Social Cost of carbon	Country-level Social Cost of Carbon, Nature Climate Change, Vol 8, October 2018, 895–900	SCC for IWT = Emission by IWT (tCO2) x $US86 per tCO_2

GHG Calculator–user instruction guide

Step 1: Input Mode



Two Input modes are available, Direct mode and Multi-modal mode.

» For the shortest route and single mode, select *Direct mode*.

» For transportation of goods using more than one mode, select *Multi-modal* option. This would enable the user to enter segment-wise trip information.

Step 2: Shipment Information

Under this option, *Commodity* to be transported can be selected from the drop down list. For the selected commodity, *Weight* has to be entered, which could either be in terms of Tonnes or Kilograms, except for containers for which the weight is in TEU.

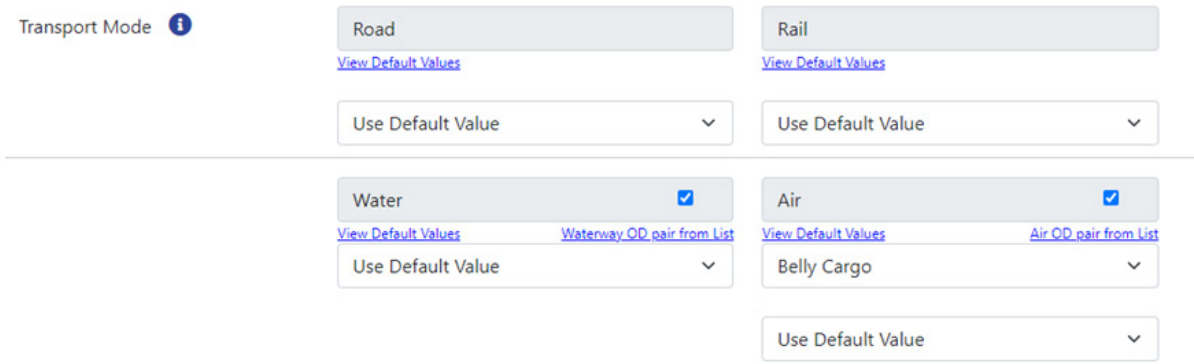
Step 3: Trip Information

Input Mode: Direct

Under this option, *Origin* and *Destination* can be selected from the search option. This option also enables you to select your ‘current location’. Shortest route is considered for direct mode.

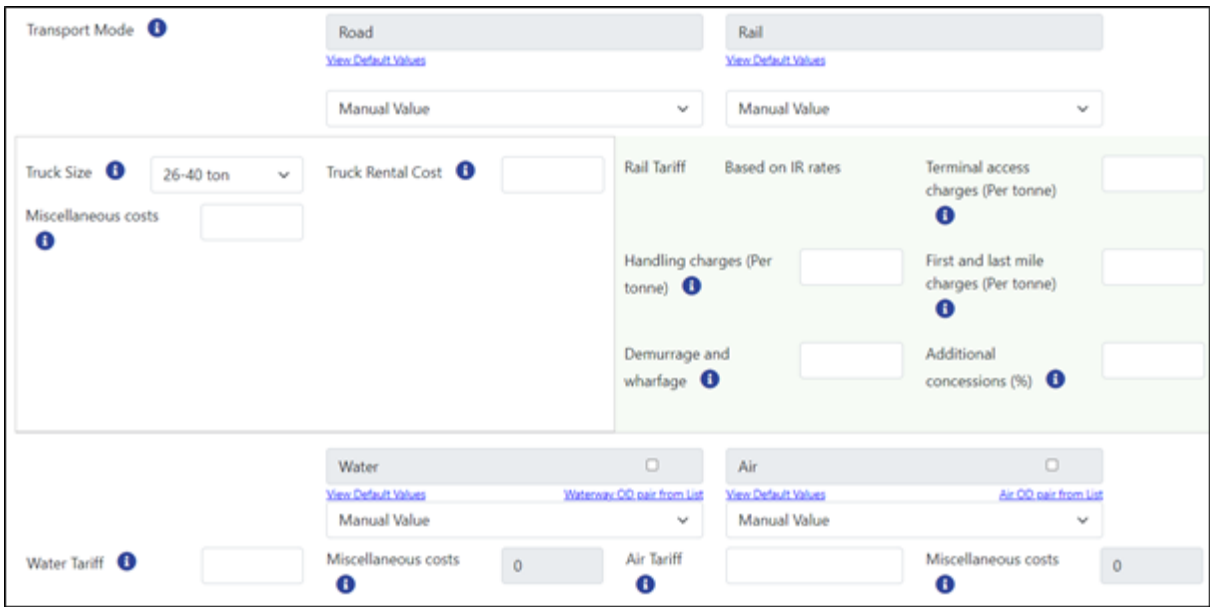
After selecting Origin and Destination, the mode of transportation needs to be selected. There are four available modes: *Road*, *Rail*, *Water* and *Air*. The user has an option to select the default values or enter the values manually. The user may select either option from the drop-down list. For Air, there are two options for transport types, *Belly Cargo* and *Dedicated Freighter*. Belly Cargo is the default transport type option. Either option can be selected from the drop-down list.

» ***Default Value***



Under this option, direct calculations will be conducted from the default values, enabled by the calculator.

» ***Manual Value***



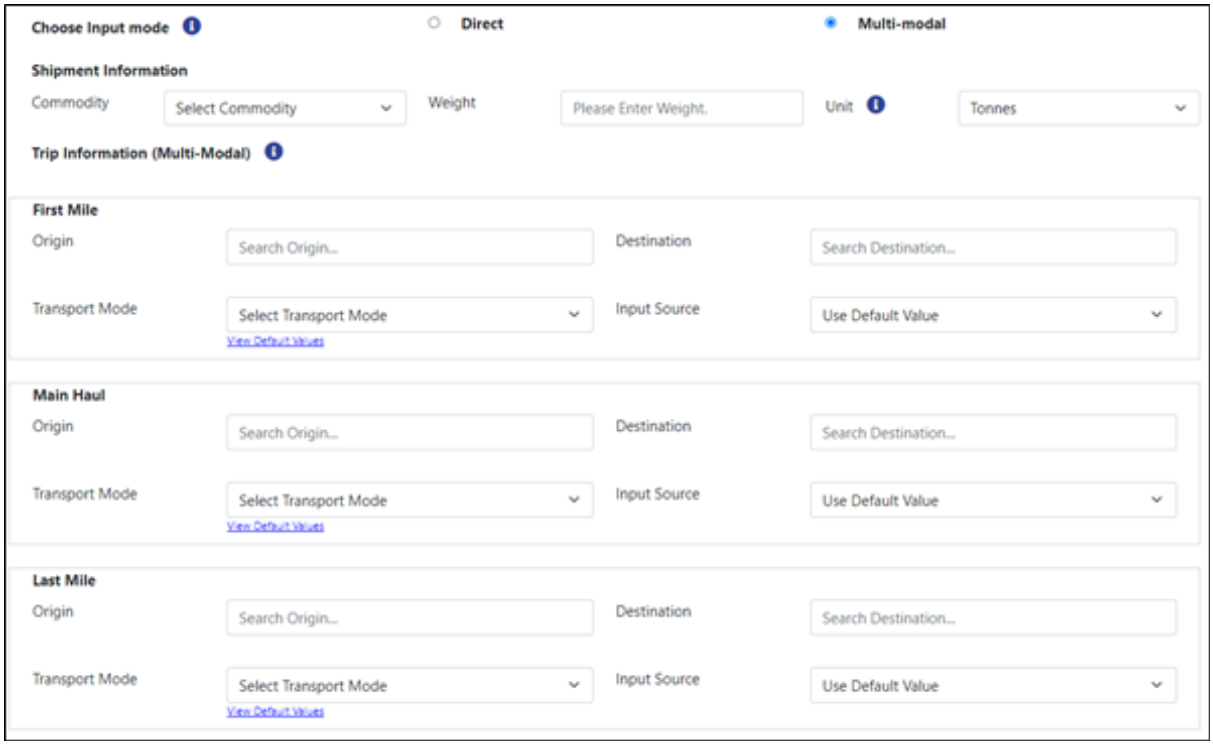
For road, select an appropriate truck size from the drop-down list. Enter the *truck rental cost* and *miscellaneous cost* (if any). *Please note that these values are in Rupees per tonne km.*

For rail, enter the *total rail tariff*, *terminal access charges*, *handling charges*, *first and last-mile charges*. *Please note that these values should be in Rupees per tonne.*

For water, enter *total water tariff* and *miscellaneous cost* (if any). *Please note that these values are in Rupees per tonne km.*

For air, enter *air tariff* and *miscellaneous cost* (if any). *Please note that these values are in Rupees per tonne km.*

Input Mode: Multi-Modal



Under this option, Origin and Destination can be selected from the search option for *First Mile*, *Main Haul* and *Last Mile* segments. This enables you to specify a particular route for a particular transport mode. Further, the cost calculation values can be carried out based on the default values or values can be manually entered, as instructed for the Direct Mode.

Step 4: Results

The results compare the emissions and the costs (freight and environmental) for road, rail, air and water. These are presented in the form of bar charts and tables.

List of Abbreviations

AERA	Airports Economic Regulatory Authority of India
ATF	Aviation Turbine Fuel
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CHC	Cargo Handling Charges
DPIIT	Department for Promotion of Industry and Internal Trade
DGCA	Directorate General of Civil Aviation
EWI	EcoTransIT World Initiative
FOIS	Freight Operations Information System
GST	Goods and Services Tax
GHG	Greenhouse Gas
HDV	Heavy Duty Vehicle
LFO	Light Fuel Oil
IWT	Inland Water Transport
IWAI	Inland Waterways Authority of India
IPCC	Inter-Governmental Panel on Climate Change
Mt	Million tonnes
MoSPI	Ministry of Statistics and Programme Implementation
OD	Origin Destination
SCC	Social Cost of Carbon
TTW	Tank to Wheel
TSP	Terminal Storage Processing
Tkm	Tonne kilometre
WTT	Well to Tank
WTW	Well to Wheel

Disclaimer

The Calculator gives indicative mode-wise comparisons related to GHG emissions and total cost of freight, and should not to be used for making business decisions.


CARGO


CARGO