MODELLING METHODOLOGY REPORT

FREIGHT MODEL FOR THE PHILIPPINES

Provided to authorities during the model training session on 24 April 2023

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A strategic freight model for the Philippines

This report details the underlying methodologies employed to develop the ITF freight model and the process of adaptation and tailoring (e.g. data sources, policy measures) conducted for the Philippines. The model is then used to provide inputs to the scenario-building dashboard to be handed over to the Department of Transportation of the Philippines. It is a reference document for any dashboard user wishing to understand the hypotheses made and the relationships between the different variables.

The scenario-building dashboard aims to provide policymakers with a user-friendly tool to identify and assess possible pathways towards the decarbonisation of the freight transport sector in the Philippines until 2050. Users can test different policy packages through the pre-set scenarios.

The dashboard is a tool for transport planners and policymakers to explore the impacts of alternate policies and programs on freight transport in terms of mode shares, transport demand, bilateral trade, carbon emissions (tank-to-wheel) and local pollutants.

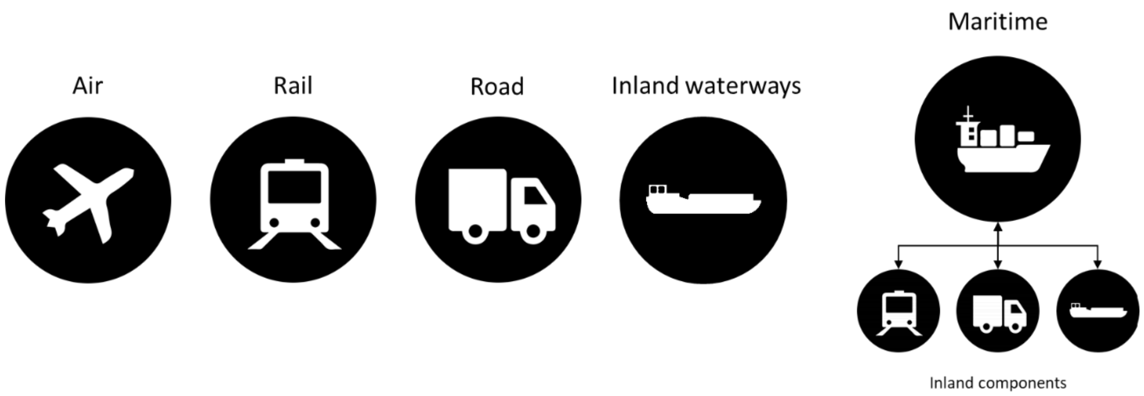
The tool will be handed over to the Department of Transportation of the Philippines in a 'model hand-over' session on 24 April 2023. The tool was developed in the context of the ITF project 'Sustainable Infrastructure Project in Asia (SIPA)', funded by the German government's International Climate Initiative (IKI).

ITF Freight Model Overview

The ITF has developed and updated its freight model to estimate the impact of policy measures on freight transport under different scenarios. The first versions of the model are described in Martinez et al. (2015), ITF (2016), and ITF (2020).

The ITF freight model assesses and provides scenario forecasts for freight flows around the globe. It is a fully integrated multi-modal network model that assigns freight flows on all major transport modes (air, inland waterways, maritime, rail, road) to specific routes, modes, and network links. The maritime freight includes the access and egress inland components, and the mode choice includes rail, road or inland waterway components. Centroids, connected by network links, represent zones (countries or their administrative units) where goods are consumed or produced.

Figure 1. Transport modes distinguished by the model



Source: ITF

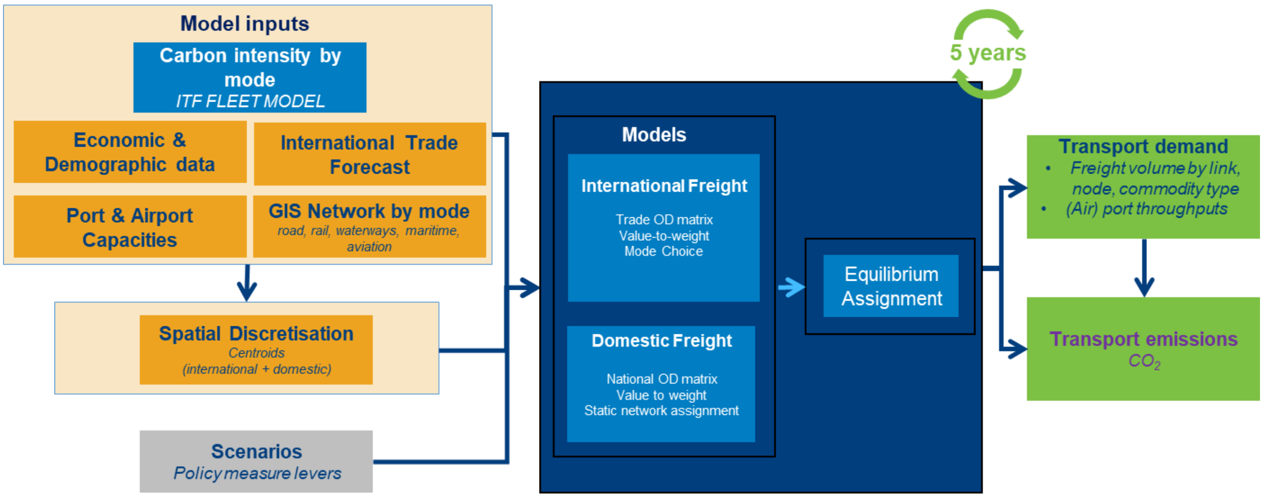
The model was developed to estimate the impact of transport and economic policy measures (e.g., the development of new infrastructure networks, the alleviation of trade barriers), technological breakthroughs or improvements (e.g., high capacity vehicles, energy transition of long-distance road freight) and environmental measures (e.g., CO_2 mitigation measures).

The most recent version of the ITF freight model integrates the (previously distinct) surface and international freight models. International and domestic freight flows are calibrated on data on national freight transport activity (in tonnes-kilometres, tkm) as reported by ITF member countries. Said data is also used to validate the route assignment of freight flows. Trade projections in value terms stem from the OECD ENV-Linkages trade model (OECD, 2021) and are converted into cargo weight (tonnes). These weight movements are then assigned to an intermodal freight network that develops over time in line with scenario settings. These define infrastructure availability, available services and related costs.

The current version of the model estimates freight transport activity for 20 commodities for all major transport modes, including sea, road, rail, air and inland waterways. The underlying network contains 8 467 centroids, where goods' consumption and production occur. Of these, 1 164 represent the origins and destinations (ODs) for international trade flows, and 7303 represent the ODs of domestic flows. Each of the 152 863 links of the network is described by several attributes. These include length, capacity, travel time (incl. border crossing times), and travel costs (per tkm).

The model framework can be found in Figure 2. Each of the components will be described in more detail in the following sections.

Figure 2. ITF Freight model framework



Source: ITF

Model inputs

The model requires inputs of four main categories: trade forecast data; network data for different modes; economic, demographic and geographical data; and initial carbon intensity data by mode (Figure 2).

Trade forecast data originate from the OECD's ENV-Linkages Computable General Equilibrium (CGE) model. This global economic model describes how economic activities are interlinked across several macroeconomic sectors and regions. The model is built primarily on a database of national economies. An economic input-output table underpins each region, usually obtained from national statistics agencies. World trade in the ENV-Linkages model is based on a set of regional, bilateral flows. All flows are expressed in monetary terms, in constant USD, using purchasing power parities as exchange rates for national currencies. The model projects international trade flows in values for 26 regions and 20 commodities up to 2060 (J. Chateau et al., 2014).

Network data is mainly based on open GIS data for different transport modes. The ITF has consolidated and integrated various modal networks into a single routable freight network. For this purpose, networks of the different modes were interconnected by introducing transport links between centroids and using data on intermodal dwelling times. Each link in the network has several characteristics, including its length, capacity, maximum speed, cost, travel times, and border crossing time (where applicable). The costs were estimated based on the network data taking into account distance- and time-based components.

Economic and demographic data include population UN-DESA (2022) and GDP data for regions (OECD, 2022) associated with each centroid. The economic characteristics of each region also include data on the contribution of the main sectors of the economy to the GDP. The main sources for detailed regional accounts are the World Bank open-data database (https://data.worldbank.org/) for single region countries, Eurostat for European countries (https://ec.europa.eu/eurostat/web/national-accounts/regional-accounts) and national accounts for other world countries over 100 million inhabitants.

Finally, data on the emissions intensity of each mode, as well as their projected changes due to technological and logistical developments over time, come from the in-house fleet model.

Model outputs

The model provides ton-kilometres (tkm) and vehicle-kilometres (vkm) for each link and node in the freight network, disaggregated by transport mode and by commodity type. As such, values can be generated for each OD pair and for single or multi-modal routes. These, in turn, can be aggregated at different geographical scales to provide information on the following:

- Freight volumes leaving or arriving at a centroid, country, region or total and the breakdown of their destinations/origins
- The modal split of the activity by country, region, or total
- Throughput for each port, airport, or border crossing

These results can be further expanded and enhanced in combination with the ITF fleet model. The demand results above are combined with information on related CO_2 intensities and technology pathways by mode to estimate transport emissions to 2050. In the case of road and rail, these coefficients and pathways vary by region, while maritime and air values are considered uniform around the globe.

The key outputs from the combination of the freight and fleet model are

- Transport CO_2 emissions by mode, country, and region.
- Activity and Emissions by vehicle type and distance bin (i.e., the vehicle types used for trips of different distances)

These last outputs are particularly relevant as it allows us to test the viability and feasibility of new and upcoming technologies and formulate policy recommendations to increase the potential benefits.

Model components

The model estimates freight activity separately at domestic and international levels, converging at the end for the shared use of surface transport infrastructure in countries. It has five main components:

1. Spatial discretisation model
2. International freight model
3. Domestic freight model
4. Equilibrium assignment module
5. Outputs module

The model is computed sequentially once all the components are set, as presented in Figure 2.

The model is updated in 5-year intervals and makes scenario forecasts up to 2050, with an adapted running template for the years 2019, 2020 and 2022 to reproduce the effect of COVID on freight demand accurately. Consequently, potential future changes to the underlying freight transport network must be accounted for. These may take the form of updates to infrastructure availability, the capacity or speed on certain transport links, or transport costs that may evolve over time, given technological changes. Such potential updates are included in the model via scenarios variables that are updated in line with a ‘calendar of development’ of the scenario. The model user can easily change those input parameters. For example, in the case of Europe, a detailed calendar representing the TEN-T network[1] development, accounting for its attributes, has been implemented. Information on European intermodal terminals, including their expected delay times, has also been incorporated[2].

[1] Detailed information available at: <https://ec.europa.eu/transport/themes/infrastructure/ten-t_en>.

[2] Detailed information available at : < http://www.intermodal-terminals.eu/database >.

Detailed model component descriptions

Spatial discretisation model (centroids)

This sub-model defines two sets of centroids: international freight centroids and domestic freight centroids.

International freight centroids

International freight centroids are used to discretise regional OD trade flows into larger production/consumption centroids. The discretisation allows for a proper breakdown of the travel path used for different types of products and leads to a better representation of actual freight flows.

An adapted *set coverage* algorithm was implemented to identify centroids based on a larger set of potential centroids. These potential centroids are all global cities with a population of fewer than 300 000 people, as identified by the United Nations in 2010 (2 539 cities) (UN, 2015). The objective function minimises the number of centroids under the constraints that only one centroid can exist within a 500km radius (in the same country), while the total of the globe’s land surface has to be attributed to a centroid.

Figure 3. International freight centroids

Source: ITF

This algorithm was adapted for some regions where increased spatial detail was desired in view of potential future studies to be carried out by the ITF. For the European Union, the adopted resolution level was the NUTS3 level in regions where a Functional Urban Area (FUA) is present and NUTS2 for the others (i.e., each of the NUTS3 or NUTS2 regions (where applicable) is represented by one centroid).

1 164 centroids were defined. Each centroid is named after the most representative city in the region that the centroid represents.

The influence area of each centroid is computed based on a raster world surface map. Each raster cell is assigned to a centroid based on its distance to the centroid, while cells within a country will always be assigned to a centroid within that same country. Each centroid is characterised by population and GDP indicators. Raster cells were linked to global population estimates (CIESIN - Columbia University, 2018) and raster-based information on GDP (Kummu et al., 2018) are used to estimate the population and GDP.

Domestic freight centroids

Domestic freight centroids define the origins and destinations of domestic freight flows. These centroids are estimated by a set coverage algorithm similar to the one described above. It uses raster-based GDP data (Kummu et al., 2018) to identify the most representative raster cell within a 100km radius.

The model produces a total of 7303 domestic centroids distributed as follows: North Africa (22), Central Africa (1020), South Africa (482), Commonwealth of Independent States (CIS) + Mongolia (823), South America (968), Central America and Caribbean (262), North America (845), ASEAN member countries (509), China (553), India (248), Japan and Korea (69), Oceania (249), Middle East (450), other Asian countries (70), European Union (452) and Other European countries and Turkey (145)).

As is the case with international freight centroids, the influence area of each domestic freight centroid is computed based on a raster world surface map. Population and GDP estimates are linked to each centroid while again respecting country boundaries (each raster cell is assigned to a centroid that lies in the same country as the raster cell, based on its distance to the centroid). Figure 4 provides an overview of the domestic freight centroids that have been defined in ITF's freight model.

Figure 4. Domestic freight centroids

Source: ITF

International freight model

This model includes a global intermodal network sub-model, underlying international trade projections, a weight-value conversion sub-model, and a mode share sub-model

Intermodal global network model

One of the main contributions of ITF's freight model is the consolidation and integration of different modal networks into a single freight network. Box 1 provides an overview of the data sources that were used to establish the respective transport network information in the model.

Box 1. Sources of information for global transport networks

- **Road network** information stems from the Global Roads Open Access Data Set (gROADS) (http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1) and OpenStreetMap (www.openstreetmap.org). Only the first and second road networks are considered (i.e. motorways, main roads and truck roads).
- For the **rail network**, the model uses data from the Digital Chart of the World (DCW) (http://www.princeton.edu/~geolib/gis/dcw.html) project that is updated with data from OpenStreetMap on rail lines and rail stations as intermodal points of connection between road and rail.
- **Maritime routes** are obtained from the Global Shipping Lane Network data of Oak Ridge National Labs CTA Transportation Network Group (http://www-cta.ornl.gov/transnet/Intermodal_Network.html), which generates a routable network with actual travel times for different sea segments. This network is connected to ports based on data from the latest World Port Index Database of the National Geospatial-Intelligence Agency (http://msi.nga.mil/NGAPortal/MSI.portal).
- Commercial **air links** between international airports were integrated using data from the OpenFlights.org database on airports, commercial air links and airline companies (www.OpenFlights.org).
- **Inland waterways** around the world were collected from the DIVA-GIS project (https://www.diva-gis.org). Their navigability was assessed by specific information about the rivers and the sections that are navigable.
- Information on **oil or gas pipelines** was also obtained from OpenStreetMap (www.openstreetmap.org).

All the above transport networks were interconnected with road-based transport links (*connectors*) that connect the centroids to the network but also interconnect the different transport infrastructures (e.g. road-rail, road/rail-ports, etc.). In order to estimate travel times for the different types of transport infrastructure, as well as dwelling times between transport modes, the model uses average speeds based on available information by region. Border crossing times were estimated based on available datasets from TAD/OECD (http://www.oecd.org/trade/topics/trade-facilitation/).

The data sources provided in Box 1 were also used to establish transport costs for the different links. These costs encompass a distance-based and a time-based cost component. The distance-based cost component for each type of infrastructure is matched to a different unit value per region or country that takes into account infrastructure quality/performance, fuel/energy costs and labour costs in the transport sector.

The methodology for these calculations was derived from Tavasszy et al. (Tavasszy et al., 2011), where the authors establish a procedure to estimate indicators for the total costs for a link/network. The values obtained for specific countries were calibrated so to match reported mode shares by these countries. The time-based cost component reflects the value of travel time. An average aggregate value of time per hour and ton of 0.196 dollars/h.ton is derived from Tavasszy et al., 2011. Commodity-specific values of time are estimated in the mode choice model, where a distinct time-sensitiveness is obtained for each commodity type and transport type (container-based cargo, dry bulk, liquid bulk, transport equipment – RoRo and general cargo - more details are provided in Table 2).

The network model computes the free flow shortest paths between all centroids for each transport mode (if the mode is available), generating inputs used in the main econometric models (weight-value model and mode share model) presented next. These inputs are:

- The cost, travel time and distance by mode to link each pair of centroids;
- The shortest paths between the centroids for each transport mode.

Underlying international trade projections

The underlying trade projections that are used as an input to the model are disaggregated into 26 world regions. This level of resolution does not allow for estimating transport flows with precision as it does not allow a proper discretisation of the travel paths of different types of products. Therefore, the model disaggregates the regional origin–destination (OD) trade flows into the set of production/consumption centroids as defined in the spatial discretisation model. The disaggregation procedure assumes a proportionality of trade to GDP and uses raster-based GDP and population information to disaggregate trade estimates at the regional level. It matches this information for the base year (2019) if the information is available in the UN Comtrade (2022) dataset. The GDP used in the disaggregation of each commodity just considers the GDP created within the respective economic sector. This is determined as a national or regional share (depending on data availability) of each economic sector multiplied by the estimated raster-based GDP. In the GDP of the EU, the NUTS3 or NUTS2 disaggregation was used to estimate this share.

Growth projections of centroids are based on the growth rates at the country level obtained from the OECD 2013 Economic Projections (Jean Chateau et al., 2014), as growth rates are available at a country level only. The split of trade activity of centroids within the same country as source/destination of trade is kept constant over time.

The resulting equation for the estimation of the trade flows between centroids (OD pairs) for each type of commodity is given by

$$T_{odk}^{y} = T_{VLk}^{y} \frac{GDP_o^y \cdot S_{of(k)}}{\sum_{v=1}^{V} GDP_v^y \cdot S_{vf(k)}} \frac{GDP_d^y}{\sum_{l=1}^{L} GDP_l^y} \tag{1}$$

Where
T_{odk}^{y} = trade values from centroid *o* to centroid *d* in year *y* for commodity *k*,
T_{VLk}^{y} = trade values from origin region *V* to destination region *L* in year *y*,
$S_{of(k)}$ = share of GDP related with the same economic sector of commodity *k* in the region or country of centroid *o*,
o, *d* = origin and destination centroids,
k = commodity *k*,
y = year of analysis,
k = centroid that belongs to the origin region *V*,
l = centroid that belongs to the destination region *L*.

Weight-value model for the international trade

The conversion of value units (dollars) into weight units (tons) of cargo was formulated as a Poisson regression model. The model estimates the rate of value-to-weight conversion, using as offset variable the natural logarithm of the trade value in million dollars and a panel term representing the sensitivity of the different commodity types to transport costs. The selection of this regression method was based on the observation of the statistical distribution of the sample that fitted better a discrete statistical distribution than continuous distributions, especially for low trade connections. The model equation is given by:

$$E(y) = F \cdot exp(a + X\beta) + \varepsilon \qquad (2)$$

Where F is the exposition factor, and X represents the systematic component of the Poisson regression model.

The model was calibrated using Eurostat and ECLAC exports data[3] provided in value and weight units and using transport cost information (stemming from the network model, as discussed above). Also, geographical and cultural variables were used to estimate the model parameters: binary variables for trade agreements, land borders and for reflecting whether two countries use the same official language were introduced. Moreover, economic profile variables were included to describe the trade relationship between countries and the scale of trade intensity. These are

- The GDP percentile of the origin country ($p\%\ GDP_i$);
- The GDP percentile of the destination country ($p\%\ GDP_j$);
- The GDP per capita percentile of the origin country ($p\%\ GDP\ capita_i$);
- The GDP per capita percentile of the destination country ($p\%\ GDP\ capita_j$);
- The natural logarithm of the GDP per capita ratio between origin and destination countries ($ln\frac{GDP\ capita_i}{GDP\ capita_j}$).

All the economic variables were defined using a relative order of countries in terms of percentiles instead of their absolute values. This is to avoid any disproportional effect in the future relation of value to weight. Any changes here are not expected to happen as it is neither assumed that products will become lighter for the majority of the commodities, especially with regards to raw materials, nor that a disruption in the market will significantly change the valuation of some commodities over others.

As a result, the values estimated by the model assume the stability of both the commodities' valuation over time and how productivity indicators may impact them. Yet, the value-weight conversion of some energy market-related products, such as crude oil, refined oil, gas and coal, will depend strongly on the price of these commodities over time. For this reason, the value-weight conversion of these commodities has been indexed to the value forecast by IEA/OECD (IEA, 2018b) to ensure consistency in terms of the forecasted volume of trade for the next decades.

The model was estimated by keeping the minimum effect of the cost log sum positive and all commodities sensitive to costs. The minimum threshold value of 0.025 was estimated for the panel terms based on the observations in the dataset. The log sum accounts for the generalised costs, incorporating the time-based and distance-based cost terms. Table 1 presents the calibration results for the model.

[3] https://sgo-win12-we-e1.cepal.org/dcii/sigci/sigci.html

Table 1. Weight-value model calibration results

Parameter	Coefficient	p-value/ level of significance
Intercept	-13.907	0.00
Economic profile of countries		
National GDP	0.123	0.02
Partner GDP	-0.074	0.11
National GDP per capita	-2.22	0.00
Partner GDP per capita	1.08	0.00
$lnGDP\ capitaiGDP\ capitaj$	0.686	0.00
Economic, geographical and cultural relations between countries		
Land border	-0.406	0.00
Same language	0.133	0.01
Trade agreement	0.114	0.03
Cost commodity panel term $logsum\ cost\ dollartonne$		
Chemicals	- 0.136	0.12
Coal	- 1.679	0.00
Crude oil	- 0.395	0.00
Electronics	- 1.161	0.00
Fishing	- 0.392	0.01
Food products	- 1.324	0.00
Forestry	- 0.244	0.01
Gas	- 2.573	0.00
Iron and Steel	- 2.335	0.00
Livestock	- 0.277	0.01
Metal products	- 1.187	0.00
Non-Ferrous Metals	- 0.025	-
Non-metallic minerals	- 1.233	0.00
Other manufacturing	- 0.025	-
Other mining	- 0.025	-
Paper, pulp and print	- 0.245	0.00
Petroleum & coke	- 1.147	0.00
Rice and crops	- 0.524	0.00
Textiles	- 0.195	0.06
Transport equipment	0.025	-
(Scale)	1	
Pseudo-ρ^2	0.73	
Correl $(y,y^a)^2$	0.92	

Source: ITF

The overall model fit is high and shows the ability of the model to predict the conversion of trade values into trade volumes (in tons). The model performs well in reproducing market patterns. The trade agreement variable reveals to be a relevant explanatory factor; more expensive goods are typically transported further away. All the economic variables were found to be significant, presenting interesting relations for the weight-value ratio. Coefficients for $p\%\ GDP_i$ and $p\%\ GDP\ capita_j$ have a positive sign, indicating that larger economies tend to export larger weights/values, and wealthier destination countries tend to import larger quantities. There is quite symmetrical behaviour in terms of the size of destination markets and their wealth, showing that for less developed countries, it is more expensive to access products in the market. When there is a large difference in wealth between countries, the model predicts the import of higher-value goods to the wealthier country.

The cultural relation between countries (set as a binary value that takes the value one if the origin and destination country have a common official language and/or had a colonial relation in the past) was also found to be significant. Such country relations lead to relatively more exports of greater-value products. Conversely, countries with a land border tend to export larger quantities due to lower export costs.

Regarding the sensitivity of commodity types to transport costs, it can be seen that bulk-type commodities (liquid or solid) tend to be quite sensitive to costs. For example, textiles and other manufacturing products are less sensitive to transport costs. The value obtained for electronic components is also quite high, showing that trade volumes for electronic products are pretty sensitive to transport costs.

Mode share model for international freight

The mode share model for international freight flows (in tonnes) defines the transport mode used for trade between any OD pair of centroids. The modes include air, rail, road, waterways and maritime transport. The overall mode attributed to each trade connection represents the longest transport leg in a multi-modal trip chain. All freight is typically shipped on multi-modal chains, especially as the first and last legs are usually different from the main mode of transport. These latter domestic components of international freight movements are often unaccounted for in the literature. The ITF model does integrate these components: In the case of maritime transport, the model distinguishes one of three access modes (rail, road or waterways, while for the other non-road modes, the access mode is always assumed to be road.

The model uses a nested multinomial logit formulation, including a time commodity type panel term and a type of freight cost panel term. The mathematic formulation is given by:

$$U_{nj} = X_{nj}'\beta + Z_s'\alpha + \varepsilon_{nj} \tag{3}$$

Where Z_s' represents characteristics of the nests, and ε follows a generalised extreme value (GEV). ε_{nj} have a joint cumulative distribution function of error terms, which is defined by

$$F(\varepsilon_{n1}, \varepsilon_{n2}, \ldots, \varepsilon_{nJ}) = exp\left(-\sum_{s=1}^{S}\left(\sum_{j\epsilon B_s} e^{-\varepsilon_{nj}/\lambda_s}\right)^{\lambda_s}\right) \tag{4}$$

Where λ_s represent the nesting parameter that characterises each nest belonging to S.

The model was calibrated using export data sets from Eurostat and ECLAC, which contain information on the value, weight and mode of transport for exports from the EU and Latin America to the rest of the world. For each OD pair, we estimate the modal share in weight by commodity group. Data on travel times and distances for each mode were taken from the global network model at the centroid level. Two geographical and economic context binary variables were added: one describing if the pair of countries have a trade agreement and the other for the existence of a land border. For every OD pair, available modes were identified (e.g. land connectivity). Some commodity classes, such as coal and crude oil, cannot be shipped by air.

The dataset contained 17 427 observations, with an average weighted mode share in weight units of 19% for road, 1% for air, 79% for sea and just 1% for rail. The calibrated model has the likelihood ratio index (pseudo-rho squared) ρ^2= 0.64, showing very strong explanatory power of the mode choice. All explanatory variables are statistically significant (see Table 2).

Table 2. Trade value international freight mode share calibration results

Variable	Coefficient	Robust t-test	Robust p-value
Mode specific constant			
Air	-2.921	-41.50	0.00
Rail	-2.024	-40.22	0.00
Road	0.150	12.42	0.00
Lambda (nest parameter)	0.754	2.56	0.00
Sea – access by road	0.963	1.87	0.01
Sea – access by rail	0.550	2.01	0.00
Sea – access by waterways	1.050	1.65	0.02
Waterways	-0.801	1.52	0.04
Time commodity panel (1 000 hours)			
Chemicals	-0.191	-6.14	0.00
Coal	-0.002	-15.21	0.00
Crude oil	-0.153	-25.64	0.00
Electronics	-0.383	-157.44	0.00
Fishing	-0.097	-99.28	0.00
Food	-0.305	-33.33	0.00
Forestry	-0.010	-32.89	0.00
Iron and Steel	-0.014	-30.19	0.00
Livestock	-0.096	-2.65	0.00
Metal products	-0.393	-32.11	0.00
Non-ferrous metals	-0.112	-23.14	0.00
Non-metallic minerals	-0.006	-52.56	0.00
Other manufacturing	-0.177	-40.15	0.00
Other mining	0.000	0.00	-
Paper, pulp and print	-0.045	-39.6	0.00
Petroleum & coke	-0.003	-15.14	0.00
Rice and crops	-0.008	-22.11	0.00
Textiles	-0.008	-2.81	0.00
Transport equipment	-0.102	-35.18	0.00
Cost type panel term (1 million dollars)			
Container-based	0.03	-4.78	0.00
Dry bulk	0.06	-10.24	0.00
General cargo	0.02	-5.38	0.00
Liquid bulk	-0.07	-13.25	0.00
Transport equipment (Ro-Ro)	-0.02	-6.51	0.05
Geopolitical variables (trade agreement effects – TA, land border – LB)			
TA (rail and road)	1.33	4.47	0.00
LB rail	0.978	28.11	0.00
LB road	1.33	92.99	0.00

Source: ITF

The results show a greater relationship between the sea alternative and low-value raw materials and non-perishable products. Transport-related variables present an interesting behaviour that clearly distinguishes sea transportation from the other available options. While increases in travel time reduce the utility of transporting by sea, cost aspects ensure the attractiveness of this mode. In general, the utility of a sea trade connection will depend on the balance between cost and travel time, often defined by specific sea routes and/or possible connections. Sea routes requiring a significant detour from the direct link are less attractive. Sea routes from Europe to Asia that do not use the Suez Canal are an example of such less attractive routes.

Air cargo has a very negative independent term due to the inability to send large volumes or because there are security concerns for specific commodities (chemicals, rubber and plastic, refined oil, livestock, other metals, other minerals, coal, iron and steel, crude oil, other mining, rice and crops and gas). The absence of direct flights is also very penalising (increasing the travel time and reducing utility significantly). Road and rail present similar utility behaviours. Yet, the alternative specific constant for rail is quite negative. This indicates that (although the cost for this mode is significantly lower than the one for road) its attractiveness is relatively low due to operational requirements that entail large delays and reliability concerns. This is partly due to the large number of rail operators involved in cross-national rail shipping.

Other important elements are geopolitical variables:

- Trade agreements between countries seem to favour land-based transport, indicating a potential simplification of border crossings procedures;
- A land border between countries favours exports through road and rail. Yet, this is stronger for road as the potential rail interoperability issues are still present.

Domestic freight model

Inversely to a traditional four steps model, the modelling of domestic freight does not follow the generation, distribution and assignment sequence. As no trade estimates between the different regions and cities of any one region are available, the model departs from the total freight activity estimation and follows a gravitational model to understand how the total trade splits into an OD matrix between the domestic freight centroids.

For each country, the gravitational impedance and the distance for each available mode among the domestic freight centroids allow the estimation of an average domestic travel distance. The total domestic freight activity (in tkm) is then divided by the average distance to obtain the average freight cargo weight. This weight can then be assigned to the network following the OD matrices and the shortest path between domestic centroids for the different available modes.

The two main steps of this model are presented next.

Estimates of total surface freight activity

Total surface freight activity in ton-kilometres is estimated by country. This includes all movements by road, rail and inland waterways inside each country's borders, encompassing transport of international and domestic nature, plus urban freight transport.

A Poisson regression model was used and calibrated on sample data from 51 countries from 2010 to 2015 with 306 observations. Observations cover all major countries that correspond to more than 80% of the world's surface freight movements (in ton-kilometre). Data assessments and extensive tests showed that using a discrete statistical distribution is more suitable than using a continuous distribution (e.g. lognormal) given the wide range of values and country behaviours. The natural logarithm of industrial- and agriculture-related GDP shows a higher correlation with freight activity than GDP *per se*. Therefore, it was used as an offset (or exposition factor) in the function. More than any other factor, this guides the trend and determines the volume of transport in each country. Other variables are related to the countries' geography, transport networks, and socio-demographic and economic structure (Table 3). The resulting equation is given by:

$$E(y) = F \cdot exp(a + X\beta) + \varepsilon \quad (5)$$

Where F is the exposition factor, and X represents the systematic component of the Poisson regression model.

Model calibration results show the number of factors that favour surface freight transport volumes. These include a country's size, the existence of large ports, the facts of being landlocked or having natural resources rents and ore-metal exports as a relevant part of the GDP (>12%). Also, having a geographical location and transport infrastructure that allows for transit plays an important role. Conversely, very high GDP per capita and population densities tend to reduce activity, meaning that richer economies are less transport intensive. Likewise, countries with higher densities show less freight transport activity, as there are only shorter distances to cover.

Table 3. Total surface freight activity calibration results

Parameter	Coefficient	z - value	Significance
Intercept	-14.890	-22723.6	0.00
Country profiles			
Connectivity for transit (1 000 000 km)	1.871	796.3	0.00
Population density (1 000 inhabitants/sqm)	-1.057	-574.9	0.00
Arable land (1 000 000 sqm)	0.516	1323.1	0.00
Dummy variables			
Inland waterways activity	0.214	522.9	0.00
Large ports (in the 90 percentile of ports by capacity)	0.191	385.4	0.00
Landlocked	0.438	640.5	0.00
Natural resources rents and ore/metal exports	0.249	668.8	0.00
Fast growing (above 5% GDP growth)	0.192	552.5	0.00
Large countries in area (>1 200 000 km^2)	0.702	1283.8	0.00
Very low GDP per capita (< 4000 USD)	0.304	358.3	0.00
Low GDP per capita (4000 – 20 000 USD)	0.364	-493.0	0.00
Very high GDP per capita (> 40 000 USD)	- 0.316	568.8	0.00
(Scale)	1		
Pseudo-ρ^2	0.94		
Adjusted ρ^2	0.99		

Note: Offset (parameter with coefficient 1) for Industrial and Agriculture related GDP. Source: ITF

All variables in the model are significant, and the pseudo-R squared has a high value of 0.94.

Data sources for freight movements include ITF's surface freight database (ITF, 2017a), Eurostat, US DOT, and other national statistical agencies. GDP composition and natural resources intensity of the economy was obtained from the World Bank database. Ports capacity comes from the data set developed for ITF (2016). The *connectivity for transit traffic* is an indicator that measures the route-kilometres that can take place in each country for movements between contiguous countries or countries that share the same trade agreements. The global road network and centroids for international trade were used for this calculation.

Part of the activity estimated by this model is already allocated to the network since it comes from international trade. The global intermodal network does not include urban activity, so the total volumes of urban freight per country are accounted for, including the estimates for emissions, but no mode choice or network allocation is performed. The share of urban versus non-urban freight transport activity in each country is obtained from the IEA's MoMo database (IEA, 2018b) as default. This information is complemented with ITF country survey information for member countries.

The activity that does not correspond to urban or international trade-related movements is subjected to mode-route choice using an *all-or-nothing* assignment procedure (see next section).

Mode route choice for domestic freight

Domestic freight activity (in tkm) is estimated in alignment with international freight activity estimates and domestic freight weights (in t).

The shortest paths between all centroids within the same countries are computed for all existent surface modes (road, rail and waterways) considering their attributes (e.g. cost and travel time). A simple gravity with the following formulation is applied:

$$V_{ij} = p_i * P_i * q_j * C_j * f(c_{ij}) \tag{6}$$

In this equation, V_{ij} denotes the transported freight from zone i to zone j, while P_i and C_j are the reported production and consumption of freight in the corresponding zones multiplied by zone-specific multiplication factors s p_i and q_j.These are multiplied by function f that determines the accessibility of the destination zone based on the generalised cost between zones c_{ij}:

$$f\left(c_{ij}\right) = e^{-\beta c_{ij}} \tag{7}$$

In this function, β is a sensitivity parameter that is estimated to be 0.00045, while c_{ij} defines the impedance between centroids (i.e. the zones that they represent), taking into account travel times and costs. The model generates a distribution of origin-destination flows by mode within the same country. The resulting matrix allows estimating the average travel distance of a freight movement and converting the tkm into weight. These flows (in weight terms) are assigned to the intermodal transport network model and are there subject to potential congestion also stemming from international traffic.

Equilibrium assignment

The model uses an iterative equilibrium assignment procedure with travel time and cost updates at every iteration (5 years). This also accounts for transport infrastructure updates in line with the 'calendar of development' that provides information on how infrastructure develops over time (e.g. accounting for TEN-T networks for Europe) - in terms of availability and/or link attributes (speed and capacity). Some components of the network are also assessed in terms of capacity and resulting congestion. Port capacity and throughput are also updated every iteration, using the information on planned port capacity expansions as reported at individual porta- or in the form of regional average growth rates. Port-specific data has been obtained from maritime studies (Drewry, 2013; OCS, 2012c, 2012a, 2012b).

At every iteration, freight transport activity by mode is assigned to the shortest/least-costly path (based on minimising the generalised cost). In the case of maritime shipments, a route choice model also considers the available .alternatives for port selection and transhipment options for every OD pair. The introduction of this procedure in the overall equilibrium assignment reduces the number of iterations required to converge. For creating the routing alternatives between each pair of centroids, the shortest path algorithm is computed between ports to generate the port-to-port segment(s) – consider both direct routing or indirect routing via a transhipment port). Transhipment ports are limited to large ports (more than 1 million TEUs of container traffic capacity, assuming an increase of this threshold value of 3% per year) with more than 25% spare capacity in the previous iteration.

The route and port choice algorithms use a path size logit model, which accounts for overlaps between alternative routes and transport costs associated with each alternative. The basis of this model can be found in (Bottom et al., 1999). The model is calibrated by minimising the difference between observed and modelled port throughputs for more than 400 major ports in the world. A detailed description of the model can be found in (Halim et al., 2016) and in (Tavasszy et al., 2011). The formal definition of the cost model is

$$\boldsymbol{C_r} = \sum_{\boldsymbol{p\in r}} \boldsymbol{A_p} + \sum_{\boldsymbol{l\in r}} \boldsymbol{c_l} + \boldsymbol{\alpha}\left(\sum_{\boldsymbol{p\in r}} \boldsymbol{T_p} + \sum_{\boldsymbol{l\in r}} \boldsymbol{t_l}\right) \tag{8}$$

where

C_r = unit cost of route r from origin centroid to destination centroid (USD/Twenty-equivalent unit, TEU),

p = ports used by the route,

l = links used by the route,

A_p = unit cost of transhipment at port p (USD/TEU),

c_l = unit cost of transportation over link l (USD/TEU),

T_p = time spent during transhipment at port p (days/TEU),

t_l = time spent during transportation over link l (days/TEU),

α = value of transport time (USD/day).

The following is the formal definition of the route choice model. The route probabilities are given by

$$P_r = \frac{e^{-\mu\,(C_r + \ln S_r)}}{\sum_{h=1}^{H} e^{-\mu\,(C_h + \ln S_h)}} \tag{9}$$

While the path size overlap variable S is defined as

$$S_r = \sum_{a\,\in\,LK_r} \frac{\mathrm{Z}_a}{\mathrm{Z}_r}\frac{1}{\mathrm{N}_{ah}} \tag{10}$$

In Equations (8) and (9):

P_r = the choice probability of route r,

C_r = generalised costs of route r,

C_h = generalised costs of route h within the choice set,

CS = the choice set with multiple routes,

h = path indicator/index,

μ = logit scale parameter,

a = link in route r,

S_r = degree of path overlap,

Lk_r = set of links in route r,

Z_a = length of link a,

Z_r = length of route r,

N_{ah} = the number of times link a is found in alternative routes.

At every iteration, the equilibrium assignment produces an all-or-nothing assignment (subject to the travel time and costs update at each assignment iteration) of all transport alternatives simultaneously. The model runs until there is a convergence of travel costs of all alternative paths for the same OD pair. The model typically converges after 5 to 10 iterations.

Calculation of the outputs

The model provides ton-kilometres (tkm) and vehicle-kilometres (vkm) for each link and centroid in the freight network, disaggregated by transport mode and commodity type. This allows calculating the corresponding values for different origin-destination pairs and routes. These outputs can be further aggregated at country and regional levels.

CO_2 emissions are estimated for each commodity either via transport activity in tkm or vkm, depending on the mode. For road transport, CO_2 is estimated via vkm, using specific load factors of trucks for the different types of commodities. Base load factors, specific for each commodity type, were obtained from the USA Commodity Flow Survey 2017[4] and Eurostat (the European Road Freight Transport (ERFT) survey).

Load factors change over time as operational improvements in freight transport are assumed to happen. These will allow reducing empty vehicle kilometres and making better use of vehicle volumes (e.g. by better packaging). For other modes, CO_2 estimates are derived by tkm. Respective CO_2 intensities per tkm were obtained from:

- ITF fleet model (road, rail and waterways)
- IMO (maritime freight) (Smith et al., 2014),
- ICAO (air cargo) (ICAO, 2018).

[4] https://www.census.gov/programs-surveys/cfs.html

Representation of the Philippines in the model and updates

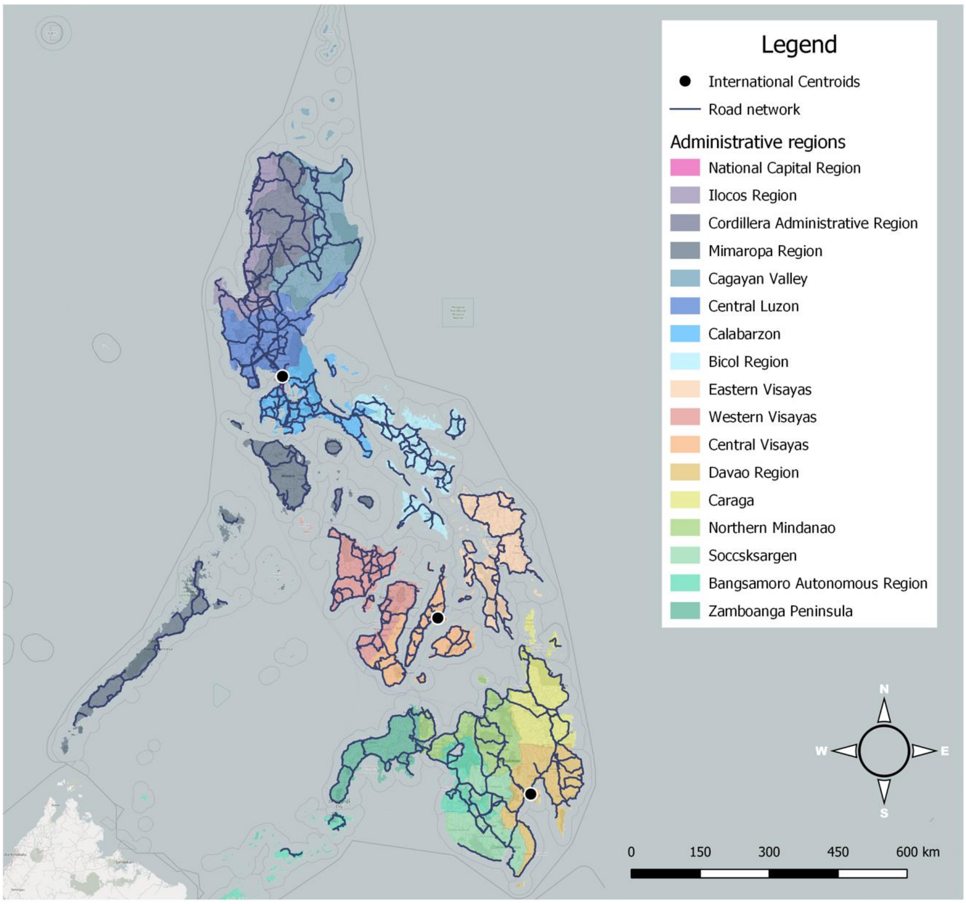
This section describes the geographic scope and data inputs for the Philippines represented in the ITF global non-urban freight model. The information in the model was updated using the inputs shared by stakeholders in the Philippines and governmental organisations.

Geographical representation of the Philippines

The model represents freight transport activities in the Philippines, including domestic, transit and international freight flows. The study area covers 298 170 square kilometres and a population of 109 million, according to the 2020 population census. The study area for this model includes the entirety of the country, split into three regions, following the geographical island groups of the Philippines: Luzon, Visayas and Mindanao.

Figure 5 shows a map of the Philippines with its 17 administrative regions, colour-coded to differentiate the three island groups. The figure also shows three cities representing international centroids in the Philippines (centres of production and consumption) included in the ITF Global Freight model.

Figure 5. Map of the Philippines' administrative regions and centroids

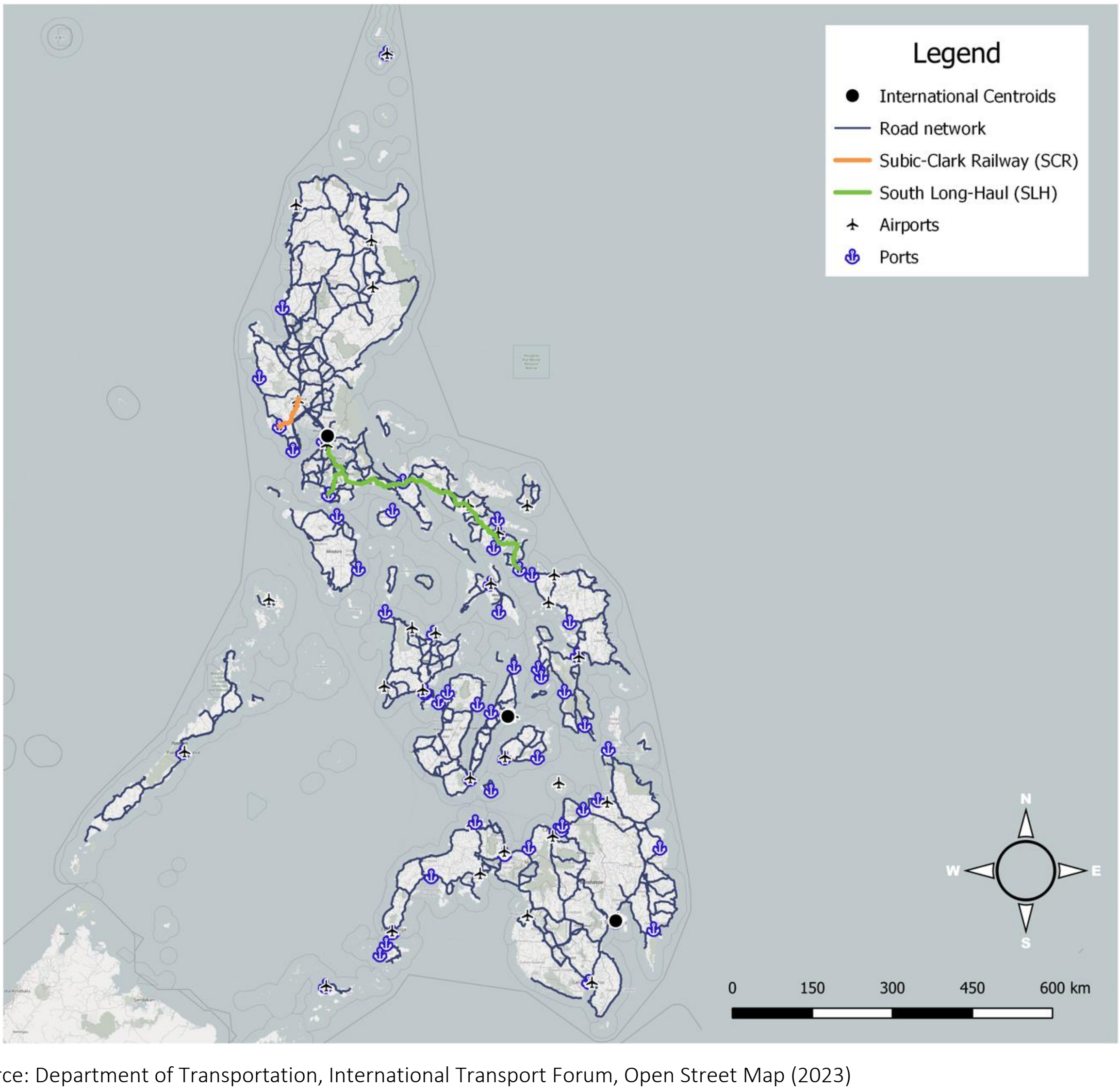


Source: Department of Transportation, International Transport Forum, Open Street Map (2023)

Philippines’ domestic and international trade

The model covers transport infrastructure linking centroids for international and domestic trade. Maritime and aviation international routes between the Philippines and other countries are specified based on port and airport locations in the GIS network. The model integrates a total of 57 ports and 36 airports in the Philippines. These transport nodes are interconnected by surface transport and nautical highways. Road trade mainly dominates surface transport, while rail and inland waterways are not implemented on a large scale in the country. Figure 6 presents two upcoming rail corridors complementing the current road infrastructure. The Subic-Clark railway will provide cargo services between two of the most significant economic zones in Luzon: Clark Freeport Zone and Subic Bay Freeport Zone. The South Long-Haul corridor is one of the most ambitious infrastructure projects in the Philippines, accounting for 581 km of railway and offering a connection between major cities on the island, such as Metro Manila, Los Baños, Batangas, Legazapi and Matnog. Phase 1 of the project, the longest corridor segment between Los Baños and Legazapi, will be operational from 2026.

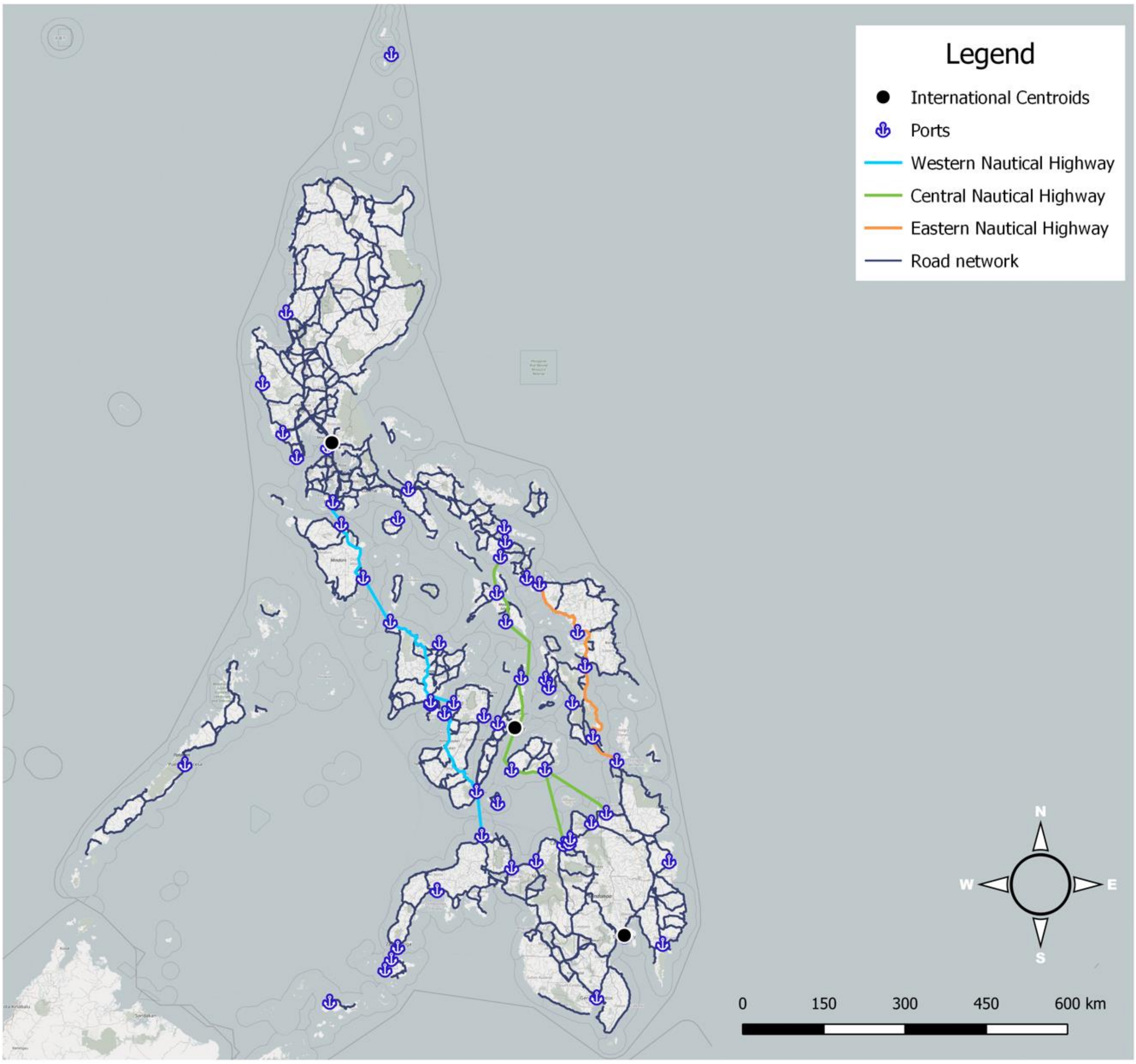
Figure 6. Transport infrastructure in the Philippines



Source: Department of Transportation, International Transport Forum, Open Street Map (2023)

Nautical highways, composed of RoRo networks located in the heart of the archipelago, were included following national traffic information reported by the DOTr. The Philippines has, in total, three main RoRo corridors that traverse the country vertically and that provide seamless transport between the major islands. The western nautical highway comprises approximately 130 nautical miles and 535 km of road and links 8 ports in the model. It connects the islands of Luzon, Mindoro, Panay, Negros and Mindanao. The central nautical highway extends approximately 190 nautical miles and 260 km of road. It connects 11 ports in the model, distributed in Luzon, Masbate, Cebu, Bohol and Mindanao. The eastern nautical highway includes about 53 nautical miles and 415 road km. Being the shortest one, it links 4 ports in the model. This highway connects Luzon, Samar, Leyte and Mindanao. In addition, the country possesses a network of horizontal ferry connections that complement the country's nautical highways and that allow reaching smaller islands.

Figure 7. Philippines nautical highways



Source: Department of Transportation, International Transport Forum, Open Street Map (2023)

Scenario description and measures

The ITF models were designed and further updated to estimate and evaluate the impact of policy measures on transport activity and related emissions. The Current scenario builds on existing policies and commitments to estimate the pathway of transport demand and related emissions. Alternative Climate Ambition scenarios aim to achieve high levels of human well-being that are more equitably distributed while drastically reducing energy and material consumption.

This chapter details the content of each measure that feeds each scenario setting in the freight model and how it affects different model components (e.g. transport time and cost, mode choice, route choice, CO_2 intensity, etc.).

Green Fleet Scenario

Truck fleet renewal

Truck fleet renewal schemes aim to increase demand for technologies that reduce the environmental impact of road transport and mobilise the required capital to ensure the supply of cleaner vehicles and the energy vectors they need. Renewal schemes reduce road freight's life-cycle greenhouse gas (GHG) emissions intensity by incentivising replacing the most polluting old trucks. Old vehicles tend to be heavier and more dependent on highly polluting fuels and technologies, like internal combustion engine vehicles (ICEV) for diesel and gasoline. These lead to high CO_2 and NO_x tank-to-wheel (TTW) emissions. In contrast, newer trucks are lighter and implement cleaner technologies that significantly reduce TTW emissions. Plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV) have proved to reduce emissions during their use to offset any additional manufacturing GHG emissions. Economic incentives can be used to increase the competitiveness of clean vehicle technologies.

Together with these incentives, renewal schemes also seek to develop the infrastructure needed to supply energy/alternative fuels to new vehicles and ease investment risks associated with low initial frequency of use of charging/refuelling infrastructure.

Measure implementation

This measure is implemented in the model as a reduction of carbon intensity per vkm for the road sector. Reference values are obtained from the scenario assumptions of the internal fleet model.

Fuel economy standards

Mandatory vehicle efficiency standards require newly registered vehicles to emit less tailpipe CO_2 emissions than a specified threshold value (usually specified in gCO_2/km or similar) by a particular target date. Alternatively, such standards may be expressed as fuel economy standards that require vehicles to surpass a specific fuel-efficiency value (usually provided in miles/gallon fuel or similar). A vehicle's tailpipe CO_2 emissions and fuel consumption are typically assessed in standardised laboratory vehicle test procedures.

Measure implementation

This measure is implemented in the model as a reduction of carbon intensity per vkm for the road sector. Reference values are obtained from the scenario assumptions of the internal fleet model.

Fleet renewal and vessel refurbishment

This measure aims at incentivising the replacement of old operating vessels, or vessel parts, to incorporate new technologies that increase fuel efficiency. Some technological measures that reduce CO2 emissions from maritime trade involve exhaust gas heat recovery as a source of energy, air lubrication, wind assistance for ships, and automated monitoring and control systems. Vessel design is equally important, with significant GHG emission reductions when implementing bulbous bows to reduce friction, slender structures, optimising hull length and fullness, lighter materials and larger vessels to maximise the efficiency per unit of work.

Incentives for promoting the uptake of alternative fuels and renewable energy also help the decarbonisation of the sector. Advanced biofuels are already available and can be complemented with other natural or synthetic fuels to compensate for their scarcity.

Measure implementation

This measure is implemented in the model as a reduction of carbon intensity per tkm for the maritime sector. Reference values are obtained from the scenario assumptions of the internal fleet model.

Seamless Intermodality Scenario

Increasing port capacity

This measure consists of increasing port infrastructure investment to improve port capacity and competitiveness. Additional sub-measures are essential to complement capacity expansions, including reduction of frictions and delays in maritime and road transport (i.e. through dredging, signalling, new road-rail access, and dry ports, etc.), new or improved road and rail network (e.g. urban bypass or dedicated rail infrastructure), and regulatory or management measures (e.g. port management system, truck queuing/appointment, etc.). Increasing the port capacity allow terminals to increase international or domestic throughputs.

Measure implementation

This is implemented in the model as increased port capacity, decreased penalty time at ports, and reduced logistics costs. Consequently, the tonnages handled at ports will increase, and the total travel time and cost will decrease, affecting the mode choice and route choice decisions.

Decreasing dwell times

Dwell time refers to the time spent by shipped goods in a multi-modal freight interface to be transferred between different modes of transport. Reducing the transit time associated with intermodal transport lowers costs and the carbon footprint of freight transport while increasing capacity and reliability. Multi-modal transfers can be more efficient when improving one of their three components. First, investments in infrastructure facilitate access for different transport modes to the node and can expand its capacity. The construction of dry ports and inland terminals associated with ports is a clear example of how to better connect maritime with surface freight. Second, improving information exchange and synchro modality between operators, using advanced Information and Communication Technologies (ICT) and the Internet of Things (IoT), also contribute to more seamless interfaces. Finally, institutional alignment is also required, not only between operators but also at a higher intergovernmental level.

Measure implementation

This is implemented in the model as a decrease in overall penalty times and a reduction in logistics costs. As a consequence, the total travel time and cost will decrease.

Asset sharing

Sharing assets (e.g. information flows, transport mechanisms or stocking spaces) can promote efficiency in resource management for logistic activities. One same enterprise, or several of them, can benefit from this sharing of assets. ICTs have only facilitated asset-sharing by decreasing information costs and providing platforms where various actors can share their assets. From an environmental point of view, sharing assets can increase logistic efficiencies by raising the occupancy rate of vehicles, for instance. Multimodality towards less carbon-intensive modes is also a possibility. Ultimately, improvements can reduce the number of trips required to deliver goods, thus reducing emissions linked to logistic activities.

Asset sharing can also bring additional benefits. Costs for enterprises can be reduced by increasing efficiencies by decreasing fuel consumption. Improvements linked to asset-sharing measures will depend on the type of activities led by the enterprises that decide to share assets. For example, sharing transport assets between food and industrial goods transporters will be more challenging. Governments may need to consider appropriate competition regulations to facilitate such asset sharing and may need to consider how such actions could be enabled (e.g. through digital platforms).

Measure implementation

This measure is implemented by adapting the load factor by commodity type in each travel mode. The load factor gains are mainly linked with freight for typically less consolidated manufacturing goods that operate in a peer-to-peer manner or individual logistics chains of companies (e.g. textile and electronics). Load factor gains can be reflected in the conversion of tkm to vkm for each commodity type.

Slow and smart steaming

Slow steaming is the practice of reducing maritime vehicle speeds. By operating ships at significantly slower speeds than their maximum speed, less fuel is consumed. This results in reduced CO2 emissions. Slow steaming has been widely adopted since 2007, mainly due to the increased fuel costs at the time. Different ship types benefit differently from slow steaming (ITF, 2023). Besides financial benefits, regulation of ship speeds could also be used to encourage slow steaming. There is also a possibility of using fuel levies to induce slow speeding through the increases in fuel prices (OECD/ITF, 2018).

M*easure implementation*

This measure yields significantly reduced CO2 emissions. A speed reduction of 10% translates into an engine power reduction of 27% (Faber et al., 2017). Lower speeds are more effective if ship design speeds of ships are also lowered (Lindstad et al., 2011). The only potential adverse effect may result from the increased travel time that will affect the transport cost of some commodities that may decide the change for faster transport alternatives (e.g., road and rail). This measure has already been tested by Halim et al. (2016).

High capacity vehicles

Increasing the capacity of the vehicles can reduce the associated emissions by reducing the vehicle kilometres required to transport the same amount of tonnes. In a seamless intermodality scenario, a shift to high-capacity vehicles can increase efficiencies.

M*easure implementation*

This measure yields significantly reduced CO2 emissions, especially in long-distance travel. This measure is implemented by adapting the load factors and the vehicle assignment in the fleet model.

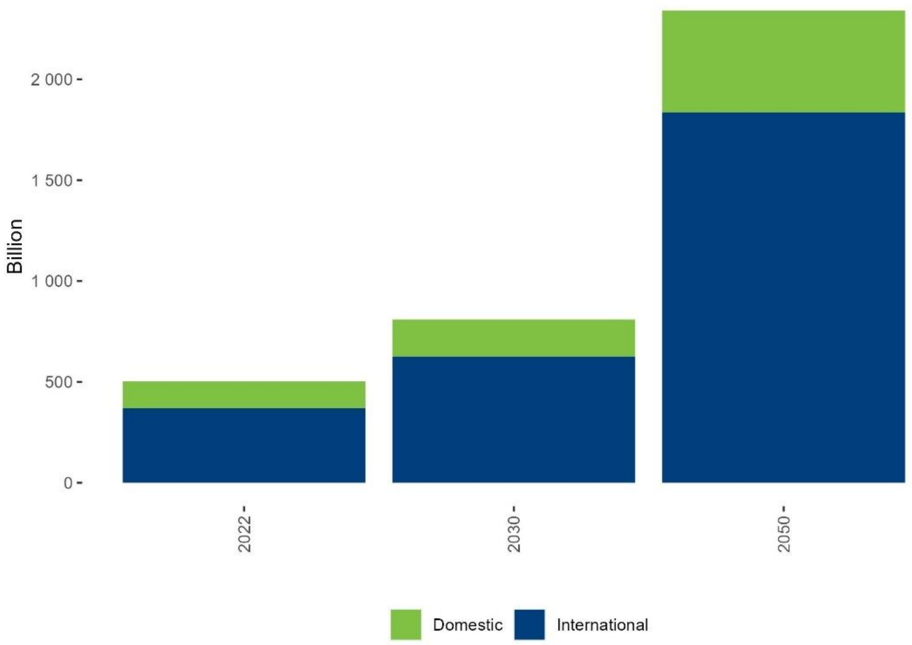
Extract from the ITF non-urban freight model

The following section will present an extract of the ITF non-urban freight model results to showcase some of the model's variables and projections. This extract contains results for the Philippines' freight transport demand, modal share, and emissions for the current ambition scenario. The results of the Philippines National Study are featured in the dashboard handed out together with the present methodological note.

Freight Demand

In the current ambition scenario, the total domestic freight demand in the base year (2022) was around 133 billion tkm and is expected to grow by almost 279%, reaching 504 billion tkm in 2050. The total international freight demand is expected to increase by 398% in 2050, from 369 billion tkm in 2022 to 1 836 billion tkm in 2050. As expected, international trade represents a more significant share of total trade in Figure 8, and its share will increase from the base year to 2050. In the current ambition scenario, the ITF non-urban freight model projects an increase in international trade share, which begins at 73% in 2022 and grows to 78% in 2050.

Figure 8. Total freight (tkm)



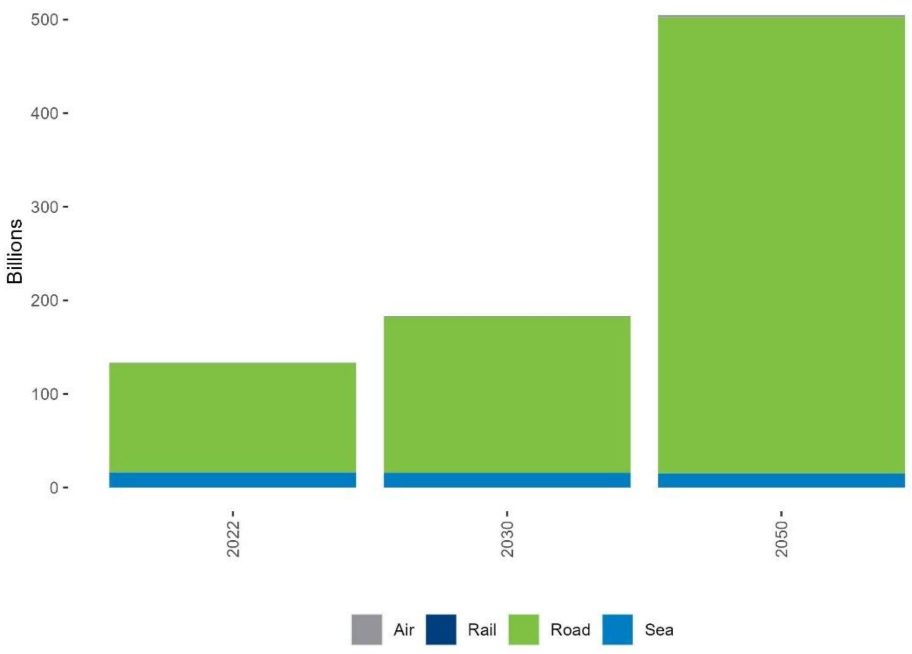
Source: ITF

Mode and cargo share

Regarding the modal share for domestic freight transport, Figure 9 exposes a clear dominance of road as the prevalent mode in the archipelago, a small and decreasing participation of sea transport and a negligible participation of air and rail freight. In 2022, transport by truck is estimated at 117 billion tkm and is set to more than triple by 2050, increasing the modal share of road over air, rail and sea. Sea freight transport, on the contrary, is expected to contract by -6% from 16 in 2022 to 15 billion tkm in 2050. As for air and rail transport, the model estimates a threefold increase of tkm between 2022 and 2050. By 2050, the estimations of the model show that road freight transport will represent 96.5%, sea will correspond to 3.0%, and air and rail transport will still represent less than 1% of total domestic freight trade.

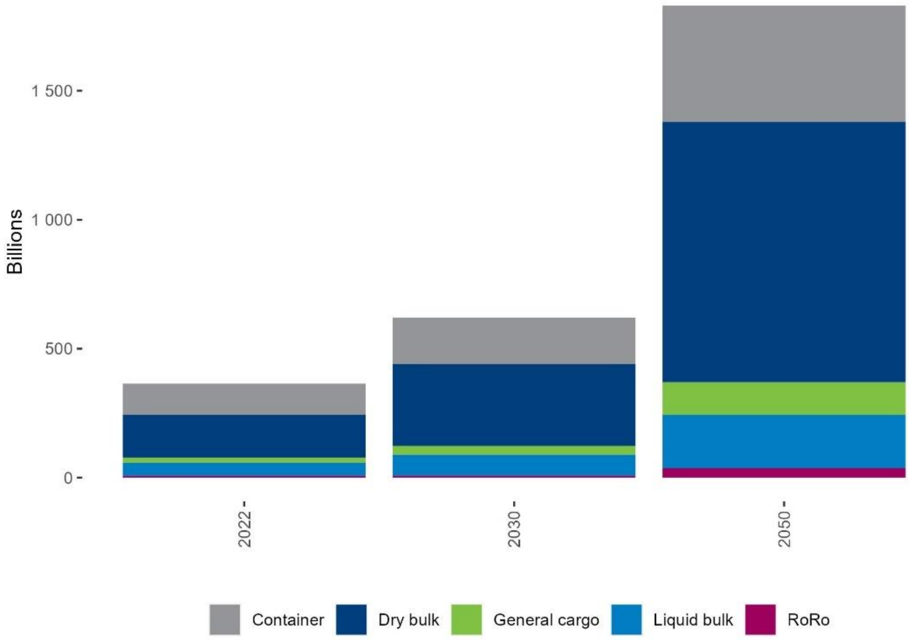
International freight trade from and to the Philippines is mainly transported by sea, representing around 99% of the total tkm. Figure 10 shows a disaggregation of the Philippines' cargo modal split. For 2022, the model estimates a prevalence of dry bulk, representing 46% of international freight trade by sea, followed by containerised trnasport (33%), liquid bulk (14%), general cargo (5%) and roll-on-roll-off (RoRo) transport (2%). Projections until 2050 show a change in cargo mode share in the Philippines. By 2050, dry bulk cargo will represent a little more than half of international sea freight transport, showing a migration towards raw materials trade. According to the results, container freight movements will experience the most significant contraction in 2050, falling to 25% of total sea-borne cargo by 2050. Transport share of other types of cargo is estimated at 11% for liquid bulk, 7% for general cargo and 2% for RoRo.

Figure 9. Domestic freight by mode (tkm-based)



Source: ITF

Figure 10. International freight by cargo mode (tkm-based)



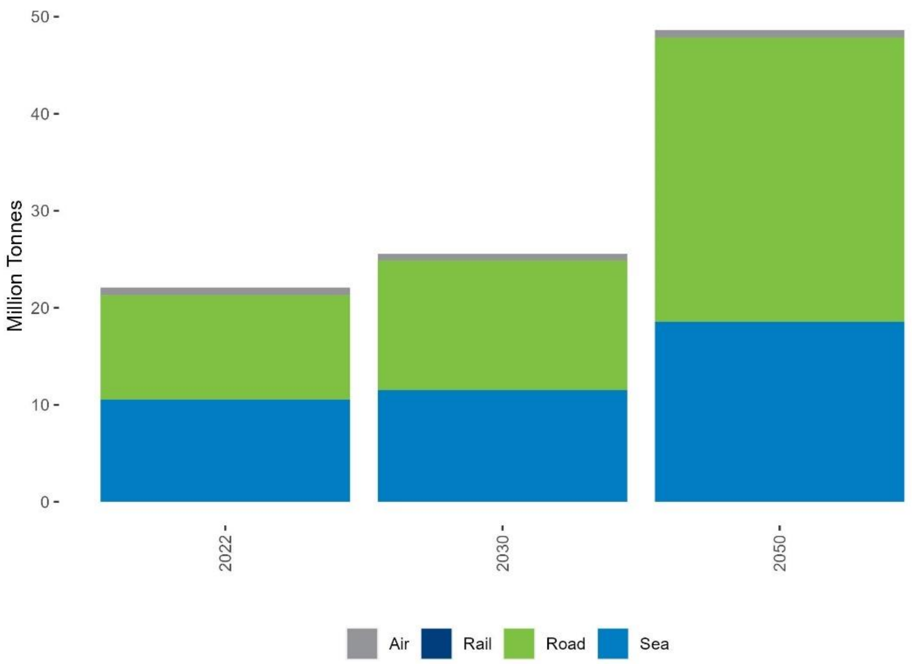
Source: ITF

CO2 Emissions

CO_2 emissions from domestic freight are estimated at 11.3 million tonnes in 2022 and are expected to grow by 165%, reaching 29.8 million tonnes in 2050. Road freight is the most significant contributor to domestic freight CO_2 emissions and represents almost all domestic emissions, accounting for 95% of the total CO_2 emissions in 2022. According to the model, the share of total emissions of road freight transport will increase to 98% in 2050.

International CO_2 emissions are smaller than their domestic counterpart, even though international trade represents a more significant share of total freight transport. CO_2 emissions in 2022 are estimated at 10.8 million tonnes, most coming from sea-borne trade. CO_2 emissions are expected to increase by 74% in 2050, reaching 18.7 million tonnes.

Figure 11. Total CO_2 Emissions by Mode (TTW-based)



Source: ITF

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