MODELLING METHODOLOGY REPORT

FREIGHT MODEL FOR AZERBAIJAN

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

International Transport Forum

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Provided to authorities in the context of the model hand-over session

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A strategic freight model for Azerbaijan

Objectives

The objective of the model is to provide policy-makers with a user-friendly tool to identify and assess possible pathways towards the decarbonisation of the freight transport sector in Azerbaijan until 2050. Users of the tool can test different policy packages through the pre-set scenarios.

The spreadsheet-based model is a tool for transport planners and policy-makers to explore the impacts of alternate policies and programs on freight transport, in terms of mode shares, mobility levels, carbon emissions (well-to-wheel) and local pollutants.

The tool is developed based on the ITF Global Freight Transport Model which was first presented in 2015[1] and enhanced in the context of the Horizon 2020 project ‘Decarbonising Transport in Europe’ in 2020[2]. This note describes in detail the data sources, modelling steps and policy measures of the tool. It is a reference document for any user of the tool wishing to understand the hypotheses made and the relationships between the different variables.

The tool will be handed over to the Ministry of Transport, Communications and High Technologies of the Republic of Azerbaijan in a ‘model hand-over’ session at a date to be defined. The tool was developed in the context of the ITF project ‘Decarbonising Transport in Emerging Economies’ (DTEE), funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Model overview

The ITF freight model assesses and provides scenario forecasts for freight flows around the globe. It is a network model that assigns freight flows on all major transport modes to specific routes, modes, and network links. Centroids, connected by network links, represent zones (countries or their administrative units) where goods are consumed or produced.

The ITF freight model integrates the 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. Reported data is also used to validate the route assignment of freight flows. Trade projections in value terms stem from the OECD trade model and converted into cargo weight (tons). These weight movements are then assigned to an intermodal freight network that develops over time in line with scenario settings.

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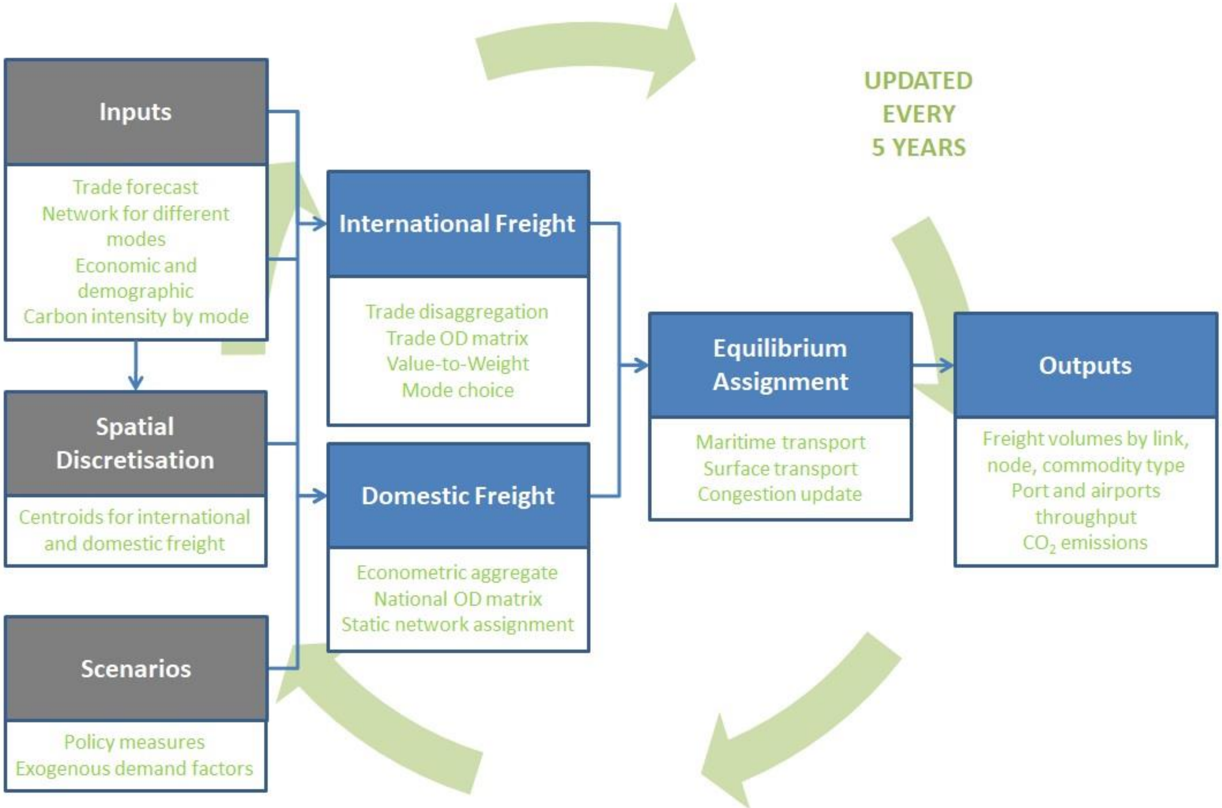
[1] Martinez, L. M., J. Kauppila and M. Castaing (2015), "International Freight and Related Carbon Dioxide Emissions by 2050: New Modeling Tool", Transportation Research Record: Journal of the Transportation Research Board, 2477, pp. 58–67, https://doi.org/10.3141/2477-07.

[2] ITF, “The ITF Non-urban Freight model – Insights and example outputs”, Horizon 2020 project “Decarbonising Transport in Europe”, 2020, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5cc3f060a&appId=PPGMS

The model estimates freight transport activity for 19 commodities for all major transport modes including sea, road, rail, air and inland waterways. The underlying network contains 8 466 centroids, where consumption and production of goods takes place. Of these, 1 163 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).

Figure 1 displays the main model components. The following sections describe the components in more detail.

Figure 1. ITF Global Freight Modelling 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 1).

Trade forecast data originate from the OECD's ENV-Linkages Computable General Equilibrium (CGE) model. The model is built primarily on a database of national economies. Each of the regions is underpinned by an economic input-output table, which is 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 25 commodities up to 2060[3].

Network data is mostly based on open GIS data for different transport modes. The ITF has consolidated and integrated different 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 a number of 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[4] and GDP data for regions[5], 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 opendata 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 International Energy Agency's MoMo model[6] and the International Maritime Organization (IMO)[7].

The Model Components Section provides further detail on the data sources.

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. This allows calculating the corresponding values for different origin-destination pairs and for single mode or multi-modal routes. These outputs can be further aggregated at country or at any larger geographical level. The results can also be grouped by origin or destination, estimating the total volume of cargo leaving or coming to a centroid or node. The model provides throughput for each port and airport, as well as for each border crossing point.

The results in ton-kilometres are also combined with information on related CO2 intensities and technology pathways by mode. In case of road and rail, these coefficients and pathways vary by region, while the values for maritime and air are considered to be uniform around the globe.

3 Chateau, J., R. Dellink and E. Lanzi (2014), "An Overview of the OECD ENV-Linkages Model: Version 3", in OECD Environment Working Papers, No. 65, , https://doi.org/10.1787/5jz2qck2b2vd-en

4 UN-DESA - The World Bank (2017), "World Population Prospects The 2017 Revision Key Findings and Advance Tables", World Population Prospects The 2017, , https://doi.org/10.1017/CBO9781107415324.004

5 OECD (2018), "OECD Economic Outlook", Vol. 104, https://doi.org/10.1787/eco_outlook-v2018-2-en

6 IEA (2018b), World Energy Outlook 2018, Paris, https://doi.org/https://doi.org/10.1787/weo-2018-en

7 Smith, T. W. P., J. P. Jalkanen, B. A. Anderson, J. J. Corbett, J. Faber, S. Hanayama, ... A. Hoen, M. (2014), "Third IMO Greenhouse Gas Study 2014", International Maritime Organization (IMO), , https://doi.org/10.1007/s10584-013-0912-3

Model components

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., CO2 mitigation measures). The model estimates separately freight activity at domestic and international level, converging at the end for the shared use of surface transport infrastructure in countries. The model consists of the following components Figure 1:

- Spatial discretisation model
- International freight model
- Domestic freight model
- Equilibrium assignment module
- Outputs module

Once all the components are set, the model is computed sequentially as presented in Figure 1. The results include the value, weight and distance travelled (with path specification) between 2010 and 2050, for each centroid pair, mode, type of commodity and year, stemming from international trade.

The model is updated in 5-years intervals and makes scenario forecasts up to 2050. Consequently, potential future changes to the underlying freight transport network need to be accounted for. These may take the form of updates to infrastructure availability, to the capacity of or speed on certain transport links, or transport costs that may evolve over time given technological changes. Such potential updates are accommodated in the model via scenarios variables.

Insights into the model components

Spatial discretisation model (centroids)

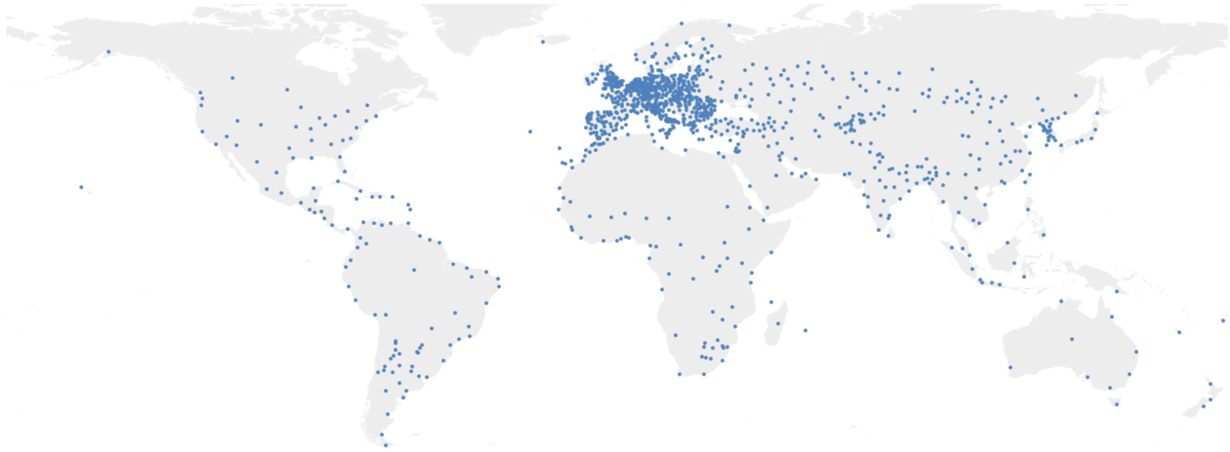
This sub-model defines two different sets of centroids: international freight centroids and domestic freight centroids.

International freight centroids

International freight centroids are used to discretise regional OD trade flows into a larger number of production/consumption centroids. To identify centroids, an adapted so-called *set coverage* algorithm was implemented on the basis of a set of potential centroids. These potential centroids are all cities around the globe with a population of more than 300 000 people, as identified by the United Nations in 2010 (2 539 cities)[8]. The algorithm 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.

As a result, 1 163 centroids were defined. Each centroid is characterised by population and GDP indicators. To obtain estimates for these indicators, raster cells were linked to global population estimates[9] and raster-based information on GDP[10]. Figure 2 provides an overview of the international freight centroids that have been defined in ITFs freight model.

Figure 2. International freight centroids



8 UN (2015), World Population Prospects, United Nations, (Vol. 1)United Nations, Department of Economic and Social Affairs, Population Division, https://doi.org/10.1017/CBO9781107415324.004

9 CIESIN - Columbia University (2018), "Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11", NASA Socioeconomic Data and Applications Center (SEDAC).

10 Kummu, M., M. Taka and J. H. A. Guillaume (2018), "Gridded global datasets for Gross Domestic Product and Human Development Index over 1990-2015", Scientific Data, Vol. 5, https://doi.org/10.1038/sdata.2018.4

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 described above. It uses raster-based GDP data to identify the most representative raster cell within a 100km radius. The model produces a total of 7303 domestic centroids. Population and GDP estimates are linked to each centroid, while respecting countries boundaries. Figure 3 provides an overview of the domestic freight centroids that have been defined in ITFs freight model.

Figure 3. Domestic freight centroids

International freight 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 airlinks 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 of the rivers and the sections that are navigable.
- Information on **oil or gas pipelines** was also obtained from OpenStreetMap (www.openstreetmap.org).

All above transport networks were interconnected with road based transport links that connect the centroids to the network, and also interconnect the different transport infrastructure (e.g. road-rail, road/rail-ports, etc.). 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 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.

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 estimating transport flows with precision as it does not allow a proper discretization 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 to the regional level.

Growth projections of centroids are based on the growth rates at the country level obtained from the OECD 2020 Economic Projections. 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 are kept constant over time.

Weight-value model for the international trade

The conversion of value units (dollars) into weight units of cargo (tons) was formulated as a Poisson regression model. The model was calibrated using Eurostat and ECLAC exports data[11] 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

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

language were introduced. Moreover, economic profile variables were included to describe the trade relation between countries and the scale of trade intensity.

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 first and last legs are usually different from the main mode of transport. 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, as shown in Figure 4), 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 model was calibrated using exports data sets from Eurostat and ECLAC, which contain information of 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).

Figure 4. Transport modes distinguished by the model

Domestic freight model

The modelling of domestic freight does not follow the traditional four-step approach, since no trade estimates between the different regions and cities of any country 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. The freight activities are then assigned to the network following the OD matrices and the shortest path between domestic centroids for the different available modes.

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). Model calibration results show the number of factors that favour surface freight transport volumes. These include a country's size, 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.

Data sources for freight movements include ITF's surface freight database, 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.

To split the total surface freight into urban and non-urban activities, the share is obtained from a binary model calibrated using the IEA's MoMo database. The split of urban versus non-urban freight is explained by the urban population size, GDP per capita level, GDP composition and natural resources intensity of the economy, urban area size, etc. The non-urban domestic freight activity 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 the domestic freight activity (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 model is calibrated to generate 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 - in terms of availability and/or link attributes (speed and capacity). Port capacity and throughput is also updated every iteration, using information on planned port capacity expansions as reported at individual port- or in form of regional average growth rates. Port-specific data has been obtained from maritime studies[12].

[12] Drewry (2013), Global Container Terminal Operators Annual Review and Forecast 2013, Global Container Terminal Operators Annual Review and Forecast 2013,

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. The model runs until there is 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.

CO2 emissions are estimated for each commodity either via transport activity in tkm or vkm, depending on the mode. For road transport, CO2 is estimated via vkm, using specific load factors of trucks for the different types of commodities. Load factors change over time as operational improvements in freight transport are assumed to happen. For other modes, CO2 estimates are derived by tkm. Respective CO2 intensities per tkm were obtained from, MoMo model from IEA (road, rail and waterways), IMO (maritime freight), and ICAO (air cargo)[13].

Changes over time of CO_2 intensities per tkm are assumed to be in line with the 'NPS' and 'EV30@30' scenarios of IEA's MoMo model.

Representation of Azerbaijan in the Global Model

This section describes the geographic scope and data inputs for Azerbaijan represented in the ITF global non-urban freight model. Some example results are also presented in the section as well, showing the forecast of international and domestic freight demand and related CO2 emissions until 2050 for Azerbaijan under the *Baseline Scenario* designed for the ITF Transport Outlook 2021.

Geographical representation of Azerbaijan

The model represents freight transport activities in Azerbaijan, including domestic, transit and international freight flows. The study area covers 86 600 square kilometres and a population of 10.2 million. The study area for this model includes the entirety of the country, split into 11 regions, following the administrative boundaries of Azerbaijan.

OCS (2012a), East Asian Containerport Markets to 2025, Ocean Shipping Consultants.

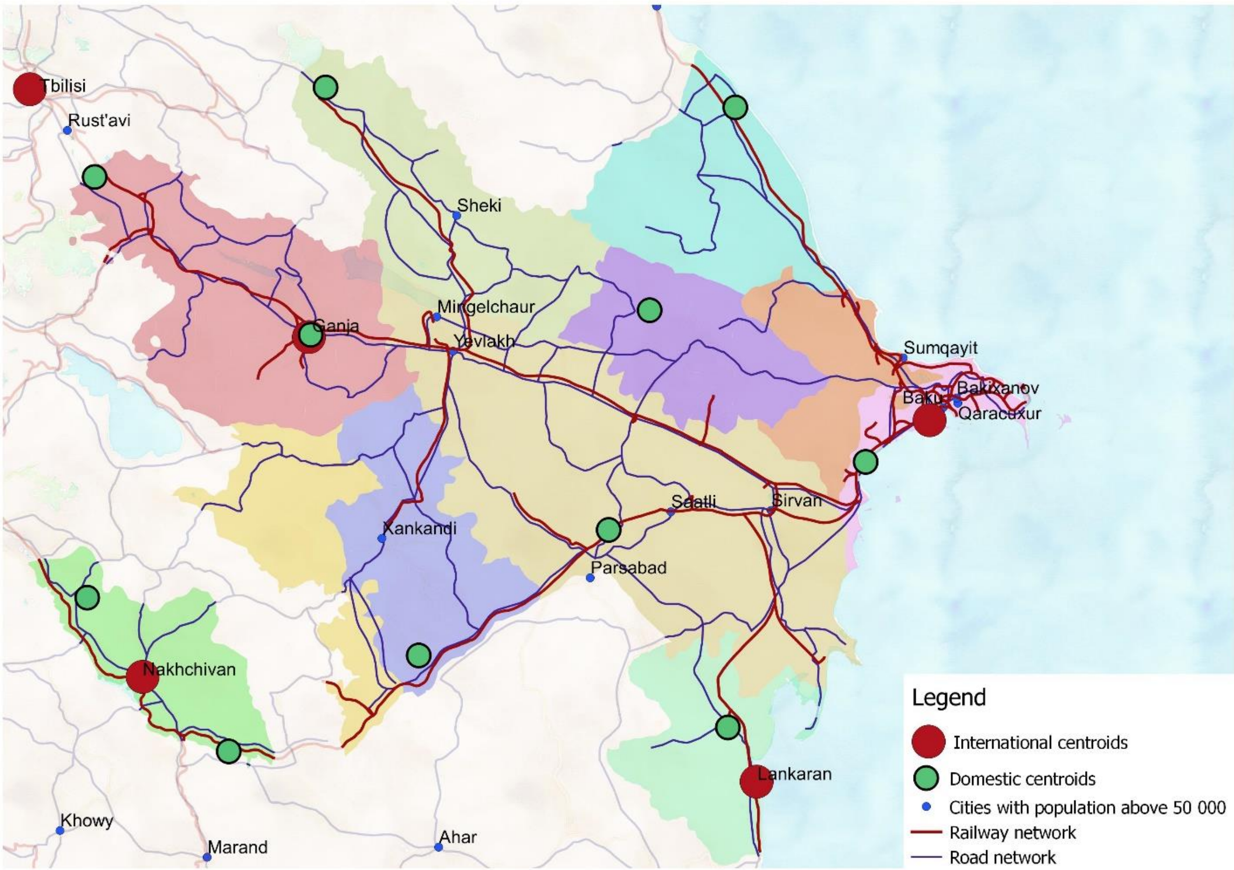
OCS (2012b), Middle East Containerport Markets to 2025, (Ocea, Ed.), Ocean Shipping Consultants.

OCS (2012c), North European Containerport Markets to 2025, Ocean Shipping Consultants.

[13] ICAO (2018), Annual Report of the Council 2017

Error! Reference source not found. shows a map of Azerbaijan with its regions, cities above 50 000 people. The figure also shows four cities that represent Azerbaijan as the main centroids (centres of production and consumption) in the ITF Global Freight model.

Figure 5. Map of Azerbaijan regions and Centroids



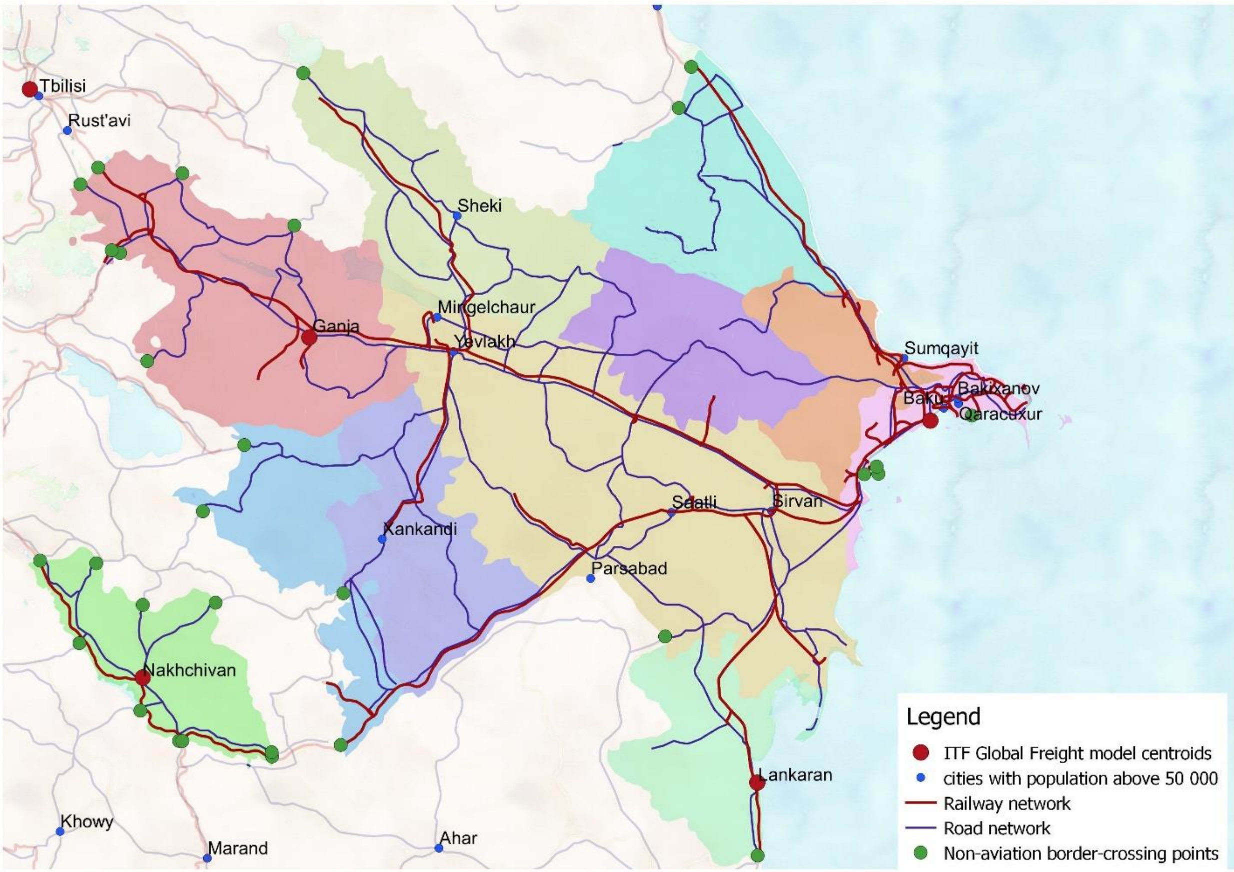
Source: ITF

Transport networks of Azerbaijan

The model covers railways and major roads in the country as well as local and international maritime and aviation routes connecting Azerbaijan to the rest of the world, as shown in Figure 6. The total number of links (all modes) representing the transport network of Azerbaijan is 335. The road network of the model covers 4200 km while the total length of the roads in Azerbaijan is 19 016 km according to the Statistical Committee of the Republic of Azerbaijan[14]. The length of the railway network covered by the model is 2068 km, which covers the entire railway network of Azerbaijan.

[14] https://www.stat.gov.az/source/transport/?lang=en

Figure 6. Map of Transport Networks and Border-crossing Points in Azerbaijan



Source: ITF

The average international border-crossing time is measured for each pair of trading countries in our model. The bordering-crossing times in the base year 2015 are obtained from the TAD directorate at the OECD. To estimate for the country pairs without such data, a regression model is developed, which explains the average border-crossing time by the trade facilitation index (also obtained from TAD/OECD) and the existence of a trade agreement between a country pair.

Table 1 presents the average border-crossing time by mode between Azerbaijan and all its import and export partners. The average road border crossing time in Azerbaijan is about 4.3 hours according to our model, which is the lowest compared to rail (7 hours) and aviation (5.7 hours).

Table 1. Average border-crossing time by mode

Mode	Average border-crossing time (hour)
Air	5.7
Rail	7
Road	4.3

Source: ITF

Results: Extract for Azerbaijan

Freight Demand

In the baseline scenario, the total domestic freight demand in the base year 2015 is around 13.2 billion TKMs, which is expected to grow by almost 150%, reaching 32.4 billion TKMs in 2050. Due to the lack of data, the domestic demand does not have the breakdown by commodity type.

The total international freight demand is expected to double by 2050, growing from 47.8 billion TKMs in 2015 to 96.5 billion TKMs in 2050. Tanker is the dominant category, accounting for 60% of the total TKMs in 2015. This share is expected to decrease to 48% in 2050 due to the foreseen reduction in the demand for oil products. The share of bulk goods will remain stable over the next 20 years, staying at around 24%, whereas the share of containerised goods are expected to grow from 3% in 2015 to 13% in 2050, and the share of general cargo will grow from 4% in 2015 to 8% in 2050. The share of RoRo goods will remain relatively stable, with a slight drop from 8.3% in 2015 to 7.5% in 2050.

Figure 7. International and Domestic Freight TKMs

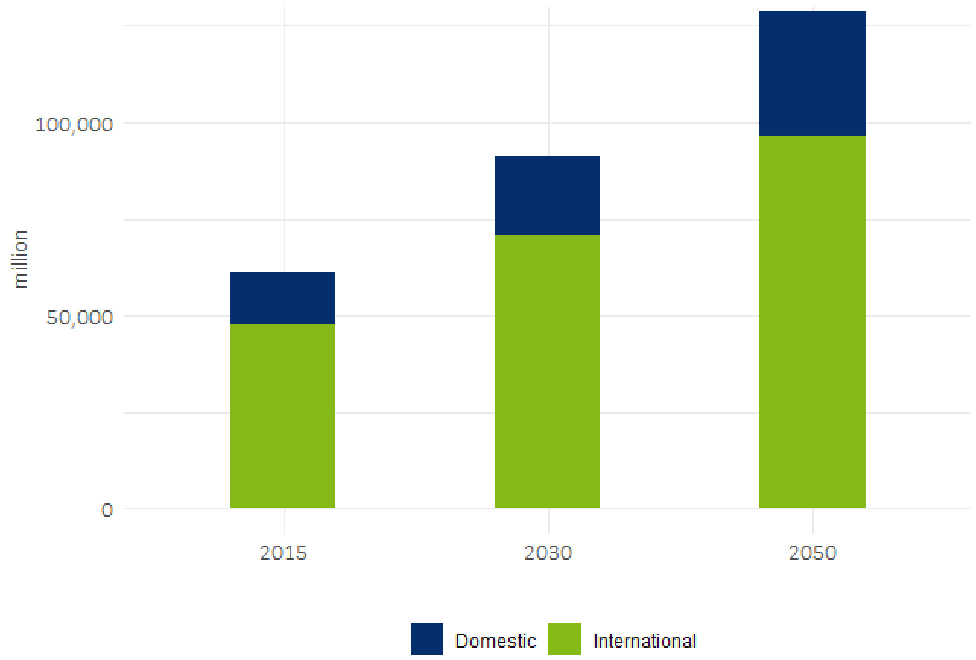
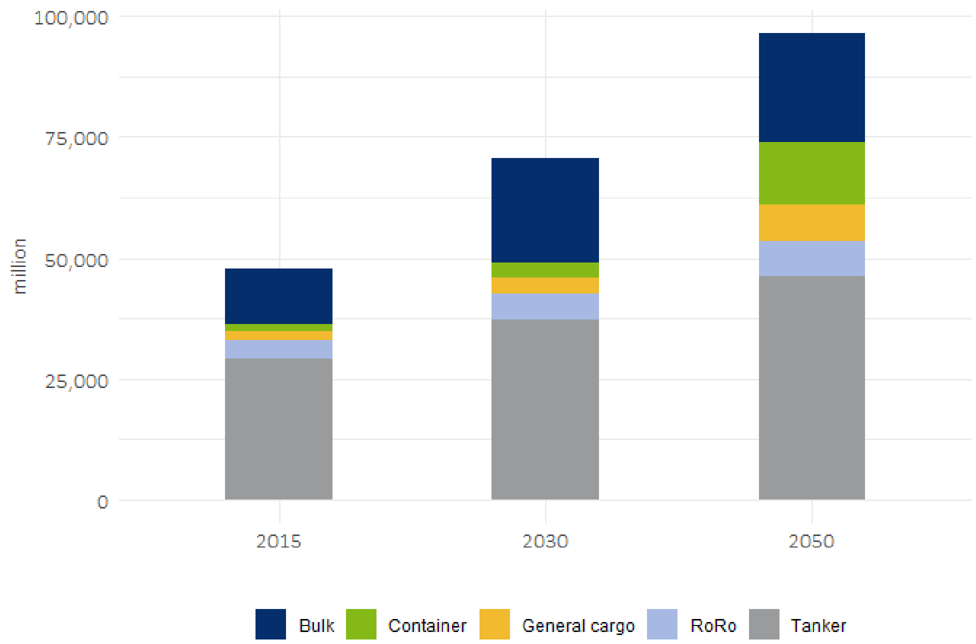


Figure 8. International Freight TKMs by Cargo Group



Mode Share

In terms of the mode share for domestic freight, the share of railway will slightly increase in the baseline scenario, from 54% in 2015 to 58% in 2050. As for road freight, the share will decrease from 46% in 2015 to 42% in 2050. The mode share pattern for the international freight is different from the domestic pattern. The dominant mode is road, accounting for 62% in 2015, and is expected to grow to 68% in 2050. Both mode shares of rail and sea will experience a slight decrease until 2050. Mode share of railway is expected to decrease from 22% in 2015 to 18% in 2050, and the mode share of sea will decrease from 16.5% in 2015 to 13.5% in 2050.

Figure 9. Modal split (tonnage-based) of domestic freight

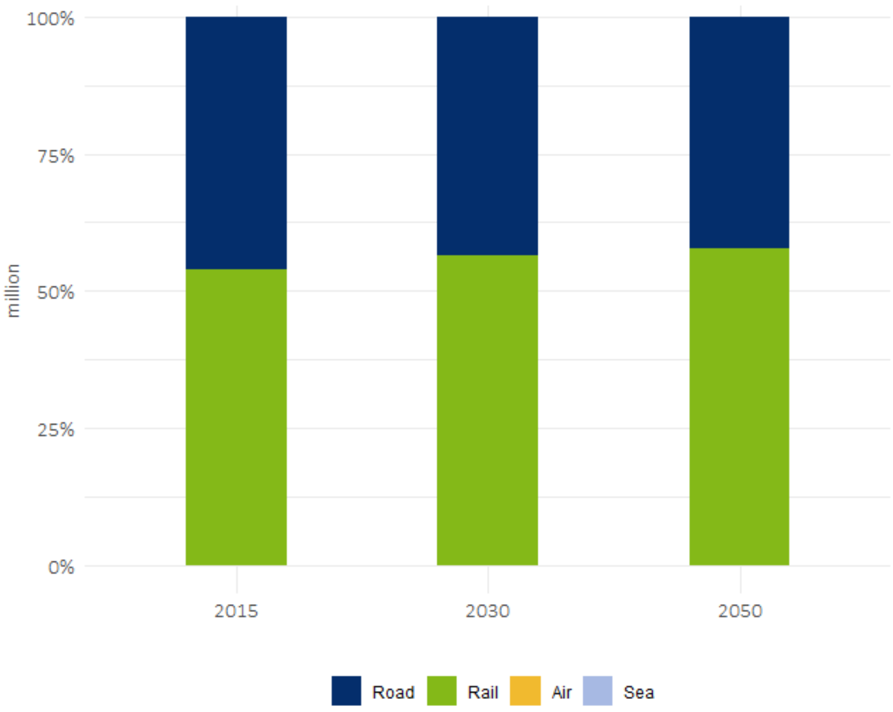
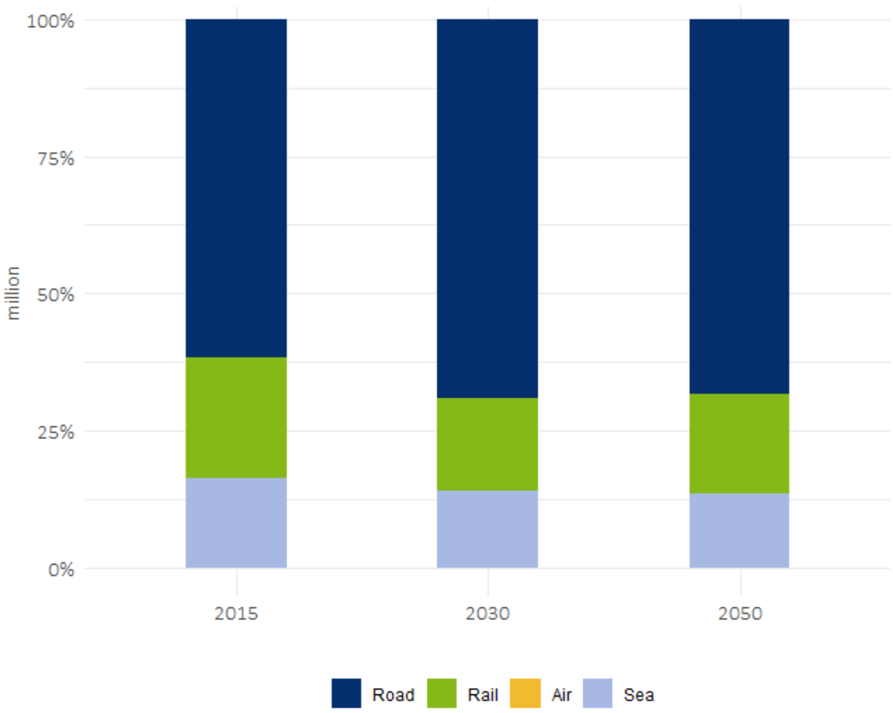


Figure 10. Modal split (tonnage-based) of international freight

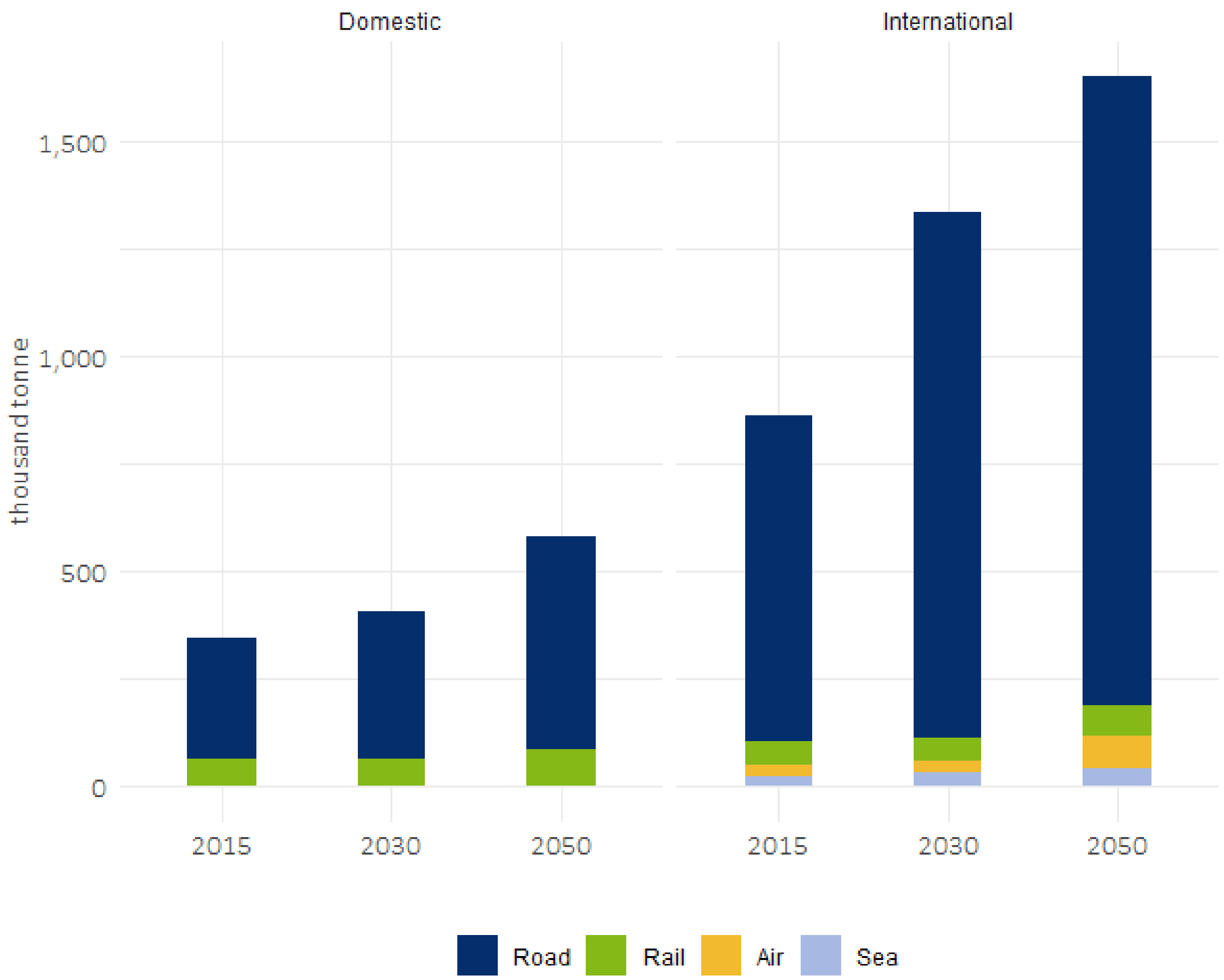


CO2 Emissions

The total CO2 emissions from the domestic freight is 0.34 million tonnes in 2015, which is expected to grow by 70%, reaching 0.58 million tonnes in 2050. Road freight is the biggest contributor to the domestic freight CO2 emissions, accounting for 81% of the total CO2 emissions in 2015, and will increase to 85% in 2050.

The international CO2 emissions are higher than the domestic counterpart. The total CO2 emissions in 2015 is about 0.86 million tonnes, with 88% coming from road sector. The amount of CO2 emissions is expected to nearly double by 2050, reaching 1.65 million tonnes (89% from road sector).

Figure 11. CO2 Emissions (WTT+TTW) by Mode and by Sector



Scenario measures

This chapter details the content of each measure that feeds the scenario setting in the freight model, and how it affects different model components (e.g. transport time and cost, mode choice, and route choice, CO2 intensity, etc.).

Economic instruments

Distance-based charges

Road pricing/charging is an old instrument widely used as a scheme to fund specific infrastructure realisation: the toll has to be paid by the users of the infrastructure (which can be a motorway, bridge, tunnel, etc.). Charges can reflect all the costs related to the infrastructure: construction, maintenance, operation, and all the externalities associated with its utilisation. Charges can vary depending on the category of vehicles: light or heavy / number of axels, Euro Norm of Emission, or some other characteristics. The charge can also vary according to the time of day/year in order to reflect congestion level (and associated externalities).

Distance-based charging is one of the road pricing mechanisms, which can be a per kilometre charge only, or with an additional base charge. The main aspect of this measure for decarbonising transport is to apply variation according to the emissions of the vehicles.

This measure is introduced in the model by affecting the cost for road freight activity. This cost increase then affects both modal split and route choice of the freight demand.

Port fees

Port fees can be differentiated on the basis of the environmental performance of the vessel. This means that port fees are differentiated on the basis of the emissions from the vessels; lesser emissions translate into discounts on port fees. Studies show that a port incentive scheme encourages the uptake and use of environmentally friendly technologies and at the same time can be profitable for ship owners.

This measure has the potential to promote the faster penetration of cleaner energy sources in the maritime sector. In the model, the effect of this measure is simulated by an elasticity of carbon intensity of maritime transport per tkm to this measure.

Carbon pricing

Carbon tax, green taxes and fuel taxes are different forms of taxes that can be applied on different transport sectors and are connected with the use of carbohydrate based fuel or the fuel-burn resulting emissions. The main difference between these different forms of taxes is whether they are applied per litre of fuel or per tonne of CO_2 emitted. Currently, carbon or fuel tax measures can be applied unilaterally by a country, or with a bilateral agreement for international transport between two countries. The CO_2 benefits of fuel or carbon taxes come mainly from demand reduction due to the increased transport cost.

This measure is introduced into the model by varying the unit cost for each mode, based on the additional cost per vkm or tkm (based on the estimated load factor by commodity), by mode, when a carbon tax is in place. This measure affects the mode choice and route choice of freight demand.

Commodity prices (oil prices)

While some alternative use of oil such as LNG/CNG, biofuels and electric are currently viable for passenger road modes, freight modes are still heavily dependent on oil-based fuel. Oil prices have a direct relation to cost of freight transport, low oil prices could also affect the effectiveness of decarbonising measures.

Different modes of freight transport are affected in different ways by oil price changes, according to their dependence on petroleum products as well as on the operators' capability to pass the higher fuel costs to their users, which very much depends on their market power. Overall, evidence show that the cost of road, aviation and maritime transport are very sensitive to the fluctuation of oil price, whereas it has much less impact on the rail transport, since fuel oil is a very small percentage of total rail operating costs.

The fluctuation of commodity prices is introduced in the model by varying the fuel cost for each mode, which then affects the mode choice and route choice decisions.

Additional sanitary measures

The health crisis, as seen with the COVID-19 outbreak, affects the total travel time, especially at border crossings, both international and domestic, due to introduced restrictive measures. Additional regulations are expected to be put in place for sanitary control, especially for certain products. This could add to additional transit time increase and overall transport cost increase for all modes.

The impact of sanitary measures is introduced into the model by varying the transit and bordering-crossing times for all the modes. Additionally, it is also expected to incur additional cost per vkm or tkm by mode. Changes in travel time and cost will eventually affect the mode choice and route choice.

Enhancement of infrastructure

Border crossing improvement

Border-crossing improvements are related to improving both the "hard infrastructure" and "soft infrastructure" that are required for freight transport crossing multiple national borders. The physical "hard infrastructure" includes cargo transhipment facilities, international border facilities, weighbridges (truck scales), and inland container depots, etc. The "soft infrastructure" consists of transport laws/regulations related to border crossing (e.g., customs clearance, quarantine), and organizational systems and resources for smoothly operating and maintaining the hard infrastructure.

Border-crossing improvement is reflected in the model as decreased delay time at the border and reduced logistics costs for each mode. Changes in transport time and cost affect both the mode choice and route choice in the model.

Road infrastructure improvement

Transport infrastructure is a long-term investment, and the environmental impacts and costs associated with the infrastructure accumulate over the course of its lifetime, both directly (in the maintenance and rehabilitation of the infrastructure) and indirectly (through congestion that may be created, or streamlined flow through the alleviation of congestion).

This measure promotes the building, reconstruction and rehabilitation of the road transport network, aspiring to increase the role of Azerbaijan as a major regional economic player and an international transit hub. This measure will increase the connectivity, capacity and speeds of the road transport system. The configuration improvements may enable a road network to handle traffic more efficiently and even reduce vehicular emission.

This impact of this measure is reflected in the modes as increased average travel speed, reduced travel time, and increased road capacity. As a result, this will affect the overall travel time and generalised transport cost, which alters the mode choice and route choice decisions in the model.

Rail infrastructure and operations improvements

This measure deals with policies promoting the development of the rail offer. It includes new links connecting big customers' facilities outside the port area, new infrastructure such as tracks and railyards or their upgrades. On the regulatory side, open access scheme can increase the operational efficiency and competitiveness, but can affect the capacity and pressure on the rolling stock and existing network.

These improvements are reflected in the model as increase in rail capacity and speed, which reduce the cost of rail freight on certain connections, and reduce time of trans-shipment of intermodal freight operations. As a result, the mode choice and route choice decisions are also effected.

Port competitiveness improvement

This measure consists of a set of sub-measures, 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 competitiveness can decrease time of cargo operation and allow terminals to increase international or domestic throughputs.

This is implemented in the modes as increase in port capacity, decrease in penalty time at ports, and reduction in logistics costs. As a consequence, the tonnages handled at ports will increase, the total travel time and cost will decrease, therefore affect the mode choice and route choice decisions.

Operations management

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, for instance by increasing the occupancy rate of vehicles. Multimodality towards less carbon intensive modes is also a possibility. Ultimately, improvements can reduce the number of trips required to deliver products, thus reducing the amounts of emissions linked to logistic activities.

Asset sharing can also bring additional benefits. Costs for enterprises can be reduced by increasing efficiencies, for instance by decreasing fuel consumption. Improvements linked to asset sharing measures will be dependent on the types of activities led by the enterprises that decide to share assets, for example, it will be harder to share transport assets between a food transporter and the industrial goods transporter. Governments may need to consider appropriate competition regulation to facilitate such asset sharing and may need to consider how such actions could be enabled (for example through digital platforms).

This measure is implemented by adapting the load factor for each 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 tkms to vkms for each commodity type. The reference values used for different scenarios are based on the efficiency increases introduced by the IEA Mobility Model in the different scenarios (IEA-NPC and IEA-SDS scenarios).

Regulatory instruments

Slow steaming and speed reduction

Speed reduction and slow steaming are the practices of reducing truck and maritime vehicle speeds, respectively. By operating trucks and ships at a lower speed can reduce the fuel consumption, which results in reduced CO2 emissions. Different truck and ship types benefit differently from the practice. There is a possibility of using fuel levies to induce slow speeding through the increases in fuel prices. Regulation of speeds could also be used to encourage slow speeding. Furthermore, lower speeds are more effective if design speeds of vehicles are brought down as well.

This measure can yield a significant reduction in CO2 emissions. Study shows that a speed reduction of 10% translates into an engine power reduction of 27%. The only potential adverse effect may result from the increase travel time that will affect the transport cost of some commodities. If the ship speed is slowed down, then that may encourage the choice for faster transport alternatives (e.g. road and rail).

Fuel economy standards – for vehicles and fuel

A low carbon fuel standard (LCFS) is a market-based policy mechanism aiming to reduce the life-cycle greenhouse gas (GHG) emission intensity of transportation fuels/energy vectors. The mechanism is grounded on the definition of progressively tightened regulatory thresholds/limits for the average life-cycle (i.e. including production, distribution and use) GHG emission intensity of transport fuels/energy vectors (typically gasoline, diesel oil and jet kerosene) distributed by regulated parties (typically fuel suppliers and/or other entities that produce, import, distribute or sell transportation fuels). Fuels with a carbon intensity that is lower than the regulated threshold generate credits; fuels with higher GHG emission intensity generate deficits. In any given year, regulated parties need to have enough credits to compensate for any deficits created by the sale of carbon intensive fuels. To ensure they meet the policy requirements in any given year, regulated entities can trade credits and use credits banked from previous years.

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 certain target date. Alternatively, such standards may be expressed as fuel economy standards that require vehicles to surpass a certain 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 standardized laboratory vehicle test procedures.

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 IEA's Mobility Model.

Low-carbon fuel development

In the long-term, decarbonising road freight will hinge on a transition to ultralow and zero-emission technologies. The development and availability of low or zero carbon fuels for use in long haul freight would be the outcome of multiple policy levers, including standards to create the need for an alternative, and likely incentives for research and development, and for the uptake of alternative fuels which may currently be more expensive than the existing fossil fuel. The adoption of a low carbon fuel would reduce the CO_2 emitted per vehicle kilometre (vkm).

The development of low carbon fuels for long distances can be encouraged through regulatory policy measures such as fuel economy standards and fuel blending mandates, pricing mechanisms and other incentives, zero emissions zones, recharging infrastructure and policies geared towards adoption of alternative fuels by large fleets.

This measure is introduced into the model by varying the cost (fuel-related) for each mode until 2050, assuming that the costs will begin higher than conventional fuels but gradually decrease and become lower than fossil fuels by 2050. The cost change will affect the mode choice and also route choices. This measure is also 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 IEA's Mobility Model.

Heavy Capacity Vehicles (HCV)

High Capacity Vehicles (HCVs) are vehicles that can carry more weight and volume than what is currently allowed in Azerbaijan. HCVs have higher efficiency than typical freight vehicles. For most HCVs, two driven axles is preferred to manage the weight and this can even go up to 3-4 axles for heavier loads.

HCVs are a solution available today that can reduce fuel consumption per unit of transported cargo, hence CO2 emissions per tonne-km moved. Their higher efficiency also means that less vehicle kilometres are needed to move the same amount of goods which decreases opportunities for accidents to occur. The ability to move the same tonnes with less vehicle kilometres also means reduced transport costs. Even though capital costs of these trucks are higher, variable costs such as fuel and labour will decrease and the latter represents a larger share of the cost structure.

The regulatory framework that enables the use of HCVs can include several safeguards like additional requirements on vehicle performance, drivers' qualifications or limits to the road network that these types of vehicles can use. Limiting HCVs to certain origin-destination (OD) commodity pairs where there are no alternative heavy modes can offer a pathway for more widespread use.

This measure is implemented in the model as a cost reduction for road freight activities, resulting in potential changes to mode shares in freight transport. It is also implemented by increasing the load factor for trucks, which is reflected in the conversion of tkms to vkms for each commodity type.

Stimulation of innovation and development

Autonomous vehicles and Platooning

Autonomous vehicles are a highly disruptive technology which will bring substantial changes in lifestyles, car ownership, travel patterns, land-use, etc. The adoption of this technology reduces costs for road freight, but also its CO2 intensity, on the other hand it can induce demand and reverse modal shift.

Authorities should provide legal clarity regarding the rights, obligations and liabilities of autonomous vehicles developers, operators, owners and insurance companies. On the operation side, the legislation will have to define liability of drivers, passengers and vehicles in different situations (such as physical damage to a person or a property, personal data leak or if a vehicle is used as a weapon of terror or for a crime), for an occupied and unoccupied vehicle. The insurance structure and compensation in case of an accident should be also defined. Finally, the authorities will have to internalise costs of driving as much as possible and to stimulate individuals, companies and organisations to own and operate the vehicles in a way which would allow to reduce both direct and external costs for the society, encouraging sharing rather than individual use of the vehicles.

Platooning refers to convoys of semi-automated vehicle convoys linked via vehicle-to-vehicle communication systems, and is regarded as a forerunner to autonomous trucks, as it is already in advanced testing. Truck platooning can decrease the wind drag of vehicles driving closely packed in a column and thereby increase fuel efficiency. But its benefits are more associated with the reduction of operational costs. In future, policy measures that increase the cost of operating road freight, such as distance based charging and carbon tax, could encourage the uptake of platooning to reduce costs.

Autonomous vehicles and platooning is implemented in the model as a cost reduction for road freight activities, resulting in potential changes to mode shares in freight transport. It is assumed the reduction of the driver costs is greater than the increases of cost stemming from the technology and the vehicle. This measure is also implemented in the model as a reduction of carbon intensity per vkm for vehicle activity. A proportion of vkms being operated by autonomous vehicles or platooning leads to a reduction in the total CO_2 intensity, thanks to higher efficiency in driving behaviours.

Electric/alternative fuel vehicle penetration

Electrification of heavy-duty vehicles is more challenging than for their lighter counterparts, due to the weight of the vehicle and the distances they cover. A battery sufficient to provide the necessary power is likely to have a significant impact on the possible payload for the vehicle, negatively impacting operational efficiency. Electric road infrastructure would overcome this by providing dynamic charging to moving vehicles. It will largely be dependent on the political will to decarbonise the sector and the available alternatives. Investment of public funds will be required for the initial development of the network, as a minimum level of coverage would need to be achieved before operators would consider electrifying their fleets. International co-operation for cross boarder routes would also be required to ensure interoperability.

Alternative-fuelled vehicles, other than electric vehicles, will also play a very important role in the decarbonisation of commercial road transport and their uptake must be accelerated by governments via incentives for operators (e.g. lower taxes) and refuelling infrastructure development.

The impact of this measure is implemented in the model by changing the carbon intensity by vkm or tkm for each mode based on the IEA assumptions for their New Policy Scenario (IEA-NPS).

Intelligent Transport Systems (ITS) and eco-driving

Intelligent Transport Systems (ITS) apply information and communication technologies to vehicles and to transport infrastructure. This provides better quality, real-time, automated data collection and processing to improve fleet management, routing and driving behaviour. ITS increases the efficiency of the transport system, which leads to a reduction in associated GHG emissions.

The impact of ITS improvements is implemented in the model by changing the carbon intensity by vkm or tkm for each mode based on the IEA assumptions for their New Policy Scenario (IEA-NPS).