# 28. Load (freight)

## Overview

### Target

The view is intended to evaluate the evolution of the load per vehicle for freight service.

The average load large-freight vehicles is assumed to change, through elasticities, on the basis of variations of the cost of moving goods.

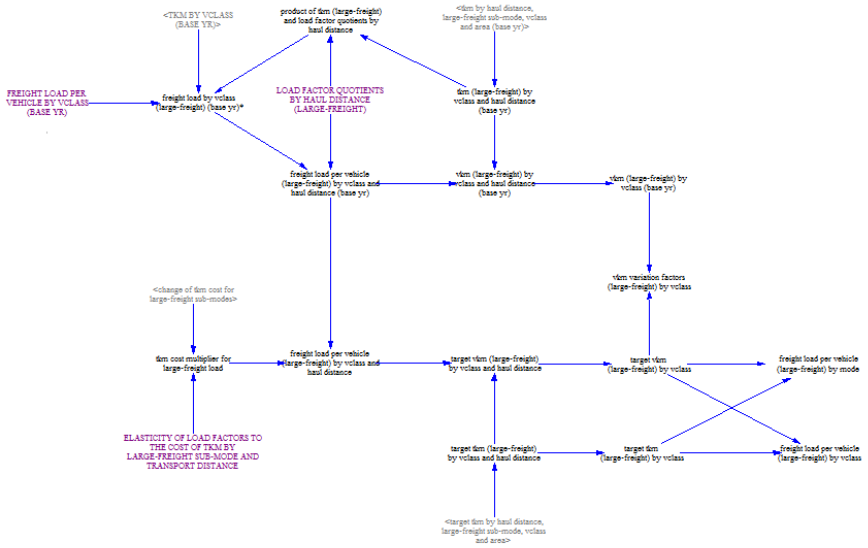
The average load of light-freight vehicles is assumed to depend on the diffusion of light-freight vehicles. It declines when the number of light-freight vehicles increases. This aims to reflect a stronger pressure towards high average vehicle loads at low income levels.

### Structure

The calculations located on the top part of the view (Figure 28.1) deal with large-freight transport sub-modes.

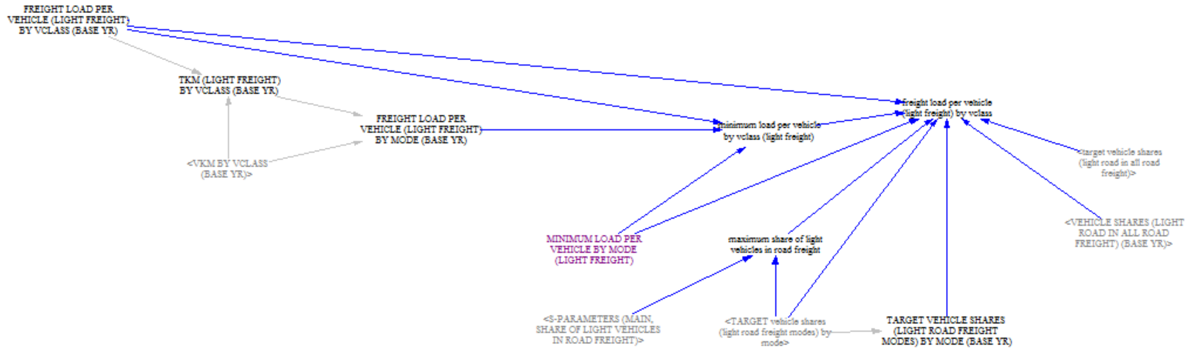
The first step consists in disaggregating the load per vehicle by haul distance. The second step concerns the effect of variations of the cost of moving goods. In a last step, the load per vehicle is aggregated by vehicle class and mode.

Figure 28.1 Load per vehicle in large-freight




The average load of light-freight vehicles (Figure 28.2) is calculated in a way that is similar to the approach adopted for personal passenger vehicles. The load per vehicle is considered inversely proportional to the number of such vehicles in the fleet. Since the number light freight vehicles per capita grows significantly when the average income increases, this depicts what happens in a situation characterized by a stronger pressure towards high average vehicle loads at low income levels.

Figure 28.2 Load per vehicle in light-freight




# Detailed description of the view

## Inputs

The average vehicle load at the base year is a user input ("User Inputs (BASE Y)" sheet of the ForFITS Excel file). It is required for each area, service, mode and vehicle class. This initial value is modified over time under the influence of several variables, as discussed in the output section.

### *Large-freight vehicles: load per vehicle by haul distance*

Following the disaggregation criteria applied to the transport activity in large-freight service, the average load per large-freight vehicle must be differentiated by haul distance. Four inputs are necessary to proceed with the calculations.

- LOAD PER VEHICLE BY VEHICLE CLASS (BASE YEAR)
  This is an exogenous input from the user (seen earlier).

- TKM BY VEHICLE CLASS (BASE YEAR)
  This is calculated in the view "activity, loads and stock aggregates ".

- TKM BY HAUL DISTANCE, LARGE-FREIGHT SUB-MODE, VEHICLE CLASS AND AREA (BASE YEAR)
  This is a variable calculated in the view "demand (large-freight, tkm)".

- LOAD FACTOR QUOTIENTS BY HAUL DISTANCE (LARGE-FREIGHT)
  This is an exogenous input that enables to distribute the load per vehicle across the different types of transport distance (SHORT, MEDIUM, LARGE, VERY LARGE). The load factor quotients are ratios that compare the load per vehicle by haul distance with respect to VERY LARGE DISTANCE taken as reference. By default, the load per vehicle in SHORT is estimated to be half of the VERY LARGE distance value, while the vehicle load in MEDIUM and LARGE distances is obtained dividing the reference value by 1.5 and 1.25 respectively.

The combination of these four inputs leads to the load per vehicle at the base year, disaggregated not only by vehicle class but also by haul distance.

The user input on the load per vehicle by vehicle class corresponds to the ratio between the tkm and vkm disaggregated at the same level. The vkm by vehicle class can be expressed as the sum across the haul distance subscript:

$$load\ by\ vehicle\ class = \frac{tkm\ by\ vclass}{vkm\ by\ vclass} = \frac{tkm\ by\ vclass}{\sum_{haul\ distances} vkm\ by\ vclass\ and\ by\ haul\ distance}$$

The vkm by vehicle class and by haul distance are equivalent to the ratio between tkm and load per vehicle, both also disaggregated by haul distance. Taking this into account, the equation above becomes:

$$load\ by\ vehicle\ class = \frac{tkm\ by\ vclass}{\sum_{haul\ distances} \frac{tkm\ by\ vclass\ and\ by\ haul\ distance}{load\ per\ vehicle\ by\ haul\ distance}}$$

The load per vehicle by haul distance equal to the load for a VERY LARGE distance (one of the outputs that will emerge from these calculations) divided by the load factor quotients by haul distance. As a result:

$$load\ by\ vehicle\ class = \frac{tkm\ by\ vclass}{\sum_{haul\ distances} \frac{tkm\ by\ vclass\ and\ by\ haul\ distance}{\frac{Load\ per\ vehicle\ in\ VERY\ LARGE}{Load\ factor\ qotients\ by\ haul\ distance}}}$$

The load per vehicle in VERY LARGE distance is isolated from the equation above, as follows:

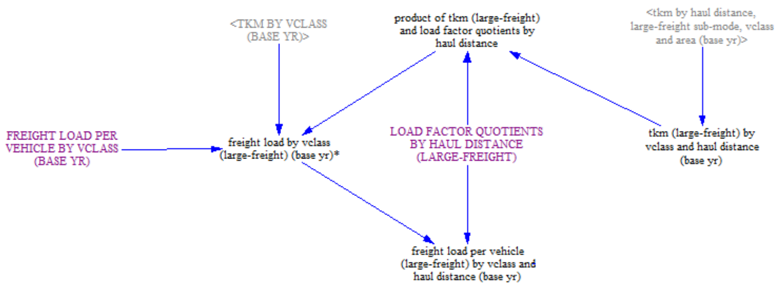
$$Load\ per\ vehicle\ by\ vehicle\ class\ in\ VERY\ LARGE\ distance\ (base\ year) = \\ = \frac{Load\ by\ vclass \times \sum_{haul\ distances} tkm\ by\ vclass\ and\ haul\ distance \times Load\ factor\ quotients}{tkm\ by\ vclass}$$

Loads for other haul distance classes are obtained applying the load factor quotients:

$$Load\ per\ vehicle\ by\ vehicle\ class\ and\ by\ haul\ distance\ (base\ year) = \\ = \frac{Load\ per\ vehicle\ by\ vehicle\ class\ in\ VERY\ LARGE\ distance\ (base\ year)}{Load\ factor\ qotients\ by\ haul\ distance}$$

Figure 28.3 reproduces the Vesnim sketcj containing the calculations explained in the earlier section. The result of the calculation flow in Figure 28.3 is the load per vehicle at the base year, disaggregated by vehicle class and by haul distance.

Figure 28.3 Large-freight - Load per vehicle at the base year by haul distance



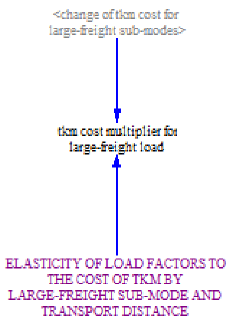
### *Large-freight vehicles: elasticities of load per vehicle with respect to cost per tkm*

The variations of the cost of moving goods are assumed to trigger changes in transport efficiency. In particular, an increase of the cost of moving goods (per tkm) is assumed to lead to an increase of the average load (with the aim to compensate the variation of the transport in the unit cost of the goods transported). The effect on vehicle load is estimated to absorb one third (on average, normally higher in local transport since in general local distribution of goods is less optimised than longer distance transport) of the total impact on transport activity (tkm) due to changes of cost per tkm. Even if explicit elasticities for load factor with respect to transport cost could not be found in literature, this reflects the idea (De Jong et al., 2010) that, in road freight transport, one third of the response to cost increase consists of “changes in transport efficiency” (the latter has been interpreted in the default assumptions as an increasing load factor).

The elasticities depend on the large-freight sub-mode and the haul distance, reflecting the existing competitors and potential alternatives for each option. All the values of the elasticities set by default were calibrated to reach around a third of tkm variations assumed by the vehicle load.

The "CHANGE OF TKM COST FOR LARGE-FREIGHT SUB-MODES" (in comparison with the cost per tkm at the base year) is the other variable needed to evaluate the impact of a percent change of the cost of moving goods over time on the average load factors (Figure 28.4). This is calculated in the view "demand (large-freight, tkm)".

Figure 28.4 Elasticities of load per vehicle with respect to cost per tkm: Vensim sketck




### *Light freight vehicles*

Fir light vehicles (TWO WHEELERS, THREE WHEELERS, and LDVS), the load per vehicle is assumed to be a linear function with negative slope of the vehicle share in the fleet, reflecting the idea that a stronger pressure towards high average vehicle loads characterizes low income levels (and a corresponding situation with few light freight vehicles per capita). The linear estimation assumed is calibrated through the base year value, and a point representing the maximum light freight vehicle share by mode.

#### Base year

Vehicle shares by mode at the base year are calculated as the product of the light vehicles share in total road freight (calculated in the view "demand (light road freight veh shares)") and the initial vehicle shares by mode (exogenous input in the "User inputs (over time)" sheet of the ForFITS Excel file).

The corresponding load per vehicle (by vehicle class) is an exogenous input of the user ("User Inputs (BASE Y)" sheet of the ForFITS Excel file).

### Maximum light freight vehicle share by mode

The asymptotic value of the S-Curve calibrated in the view "demand (light road freight veh shares)" represents the maximum light freight vehicle share, i.e. the maximum share that light vehicles could reach in total road freight. The product between this value and the shares from the user (entered in the "User inputs (over time)" sheet of the ForFITS Excel file), needed to distribute the shares across the different light freight modes, provides the maximum vehicle share by mode.

The minimum vehicle load by mode is an exogenous input set by default to 0.01 t (10 kg) for TWO WHEELERS, 0.03 (30 kg) for THREE WHEELERS and 0.4 t (400 kg) for LDVS. This input is disaggregated at the vehicle class level proportionally to the load per vehicle by vehicle class at the base year (an exogenous input from the user) and the same variable disaggregated only by mode, as follows:

$$Minimum\ load\ by\ vclass =$$
$$= Minimum\ load\ by\ mode\ (exogenous\ input) \times \frac{Load\ by\ vclass\ at\ the\ base\ year\ (exogenous\ input)}{Load\ by\ mode\ at\ the\ base\ year\ \ (to\ be\ calculated)}$$

The vehicle load by mode at the base year is calculated through the aggregates of tkm and vkm at the mode level both obtained from the endogenous input "VKM BY VCLASS (BASE YR)" from the view "activity, loads and stock aggregates":

$$Load\ per\ vehicle\ by\ mode\ at\ the\ base\ year = \frac{tkm\ by\ mode\ at\ the\ base\ year}{vkm\ by\ mode\ at\ the\ base\ year}$$

$$Load\ per\ vehicle\ by\ mode\ at\ the\ base\ year =$$
$$= \frac{\sum_{vclasses} vkm\ by\ vclass\ at\ the\ base\ year \times load\ per\ vehicle\ by\ vclass\ at\ the\ base\ year}{\sum_{vclasses} vkm\ by\ vclass\ at\ the\ base\ year}$$

## Outputs

### *Large-freight vehicles – Base year outputs*

For large-freight vehicles (LARGE ROAD, RAIL, AIR, VESSELS), the load per vehicle by haul distance and the transport activity (tkm) enable to calculate the vkm by haul distance at the base year:

$$vkm\ by\ vehicle\ class\ and\ haul\ distance =$$
$$= \frac{tkm\ by\ vehicle\ class\ and\ haul\ distance\ (from\ the\ view\ "demand\ (large-freight, tkm)")}{Load\ per\ vehicle\ by\ vehicle\ class\ and\ haul\ distance\ (calculated\ input)}$$

The latter are then aggregated at the vehicle class level:

$$vkm\ by\ vehicle\ class = \sum_{haul\ distances} vkm\ by\ vehicle\ class\ and\ haul\ distance$$

### *Large-freight vehicles – Outputs over time*

The load per vehicle by haul distance over time results from the product of its value at the base year and the multiplier that considers the effect of the cost per tkm through elasticities:

$$Load\ per\ vehicle\ by\ vehicle\ class\ and\ by\ haul\ distance\ (over\ time) =$$
$$= Load\ per\ vehicle\ by\ vehicle\ class\ and\ by\ haul\ distance\ (base\ year) \times Cost\ multiplier$$

Where:

$$Cost\ multiplier =$$
$$= 1 + \%\ change\ of\ tkm\ cost \times Cost\ elastiticity(depends\ on\ sub - mode\ and\ haul\ distance)$$

The target vkm by haul distance is projected over time according to the definition of tkm (product of vkm and average load), reversed:

$$target\ vkm\ by\ vehicle\ class\ and\ haul\ distance =$$
$$= \frac{target\ tkm\ by\ vclass\ and\ haul\ distance\ (from\ the\ view\ "demand\ (large - freight, tkm)")}{Load\ per\ vehicle\ by\ vehicle\ class\ and\ haul\ distance\ (over\ time)}$$

The load per vehicle, by vehicle class and by mode, is calculated from the corresponding values of tkm and vkm:

$$Load\ per\ vehicle\ by\ vehicle\ class\ (over\ time) = \frac{target\ tkm\ by\ vehicle\ class}{target\ vkm\ by\ vehicle\ class}$$

$$Load\ per\ vehicle\ by\ mode\ (over\ time) = \frac{target\ tkm\ by\ mode}{target\ vkm\ by\ mode}$$

Where:

$$Target\ tkm\ by\ vehicle\ class = \sum_{haul\ distances} target\ tkm\ by\ vclass\ and\ haul\ distance$$

$$Target\ tkm\ by\ mode = \sum_{modes,\ haul\ distances} target\ tkm\ by\ vclass\ and\ haul\ distance$$

$$Target\ vkm\ by\ vehicle\ class = \sum_{haul\ distances} target\ vkm\ by\ vclass\ and\ haul\ distance$$

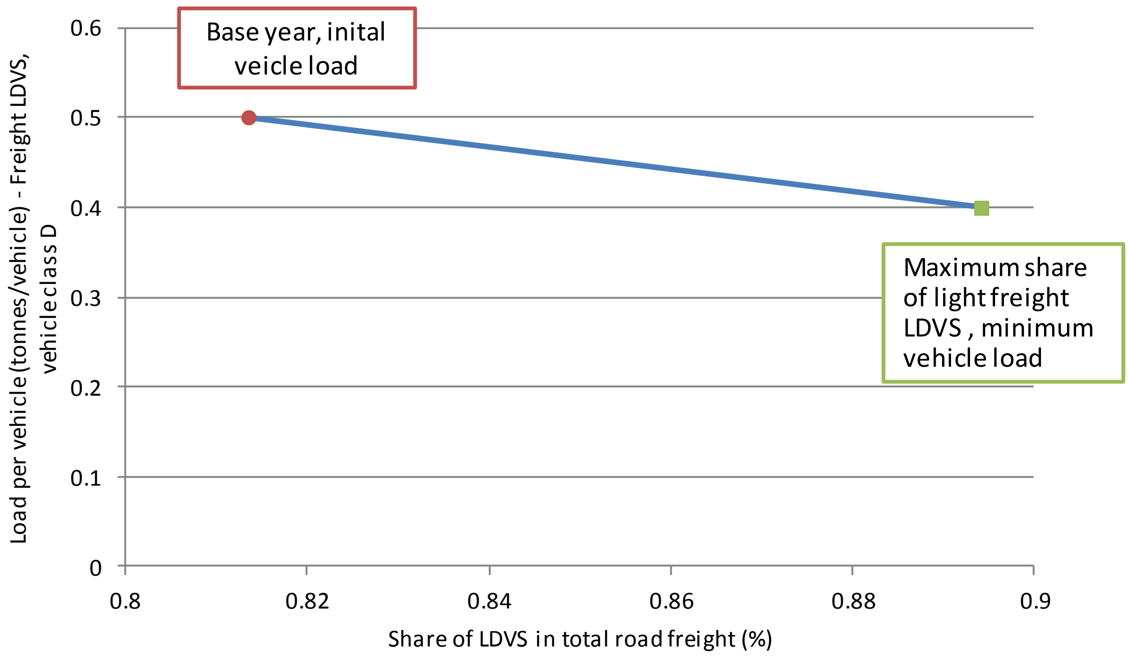
$$Target\ tvkm\ by\ mode = \sum_{modes,\ haul\ distances} target\ vkm\ by\ vclass\ and\ haul\ distance$$

*Note:* the view includes the calculation of the "VKM VARIATION FACTORS (LARGE-FREIGHT) BY VCLASS" (ratio of target vkm by vehicle class and vkm at the base year). This variable is used in the view "travel per vehicle (freight)" to determine the evolution of the annual travel per vehicle.

### *Light freight vehicles*

Figure 28.5 shows an example (for LDVS, vehicle class D) of the linear interpolation defining the load per vehicle for light-freight vehicles.

Figure 28.5 Assumed evolution of load on light-freight vehicles



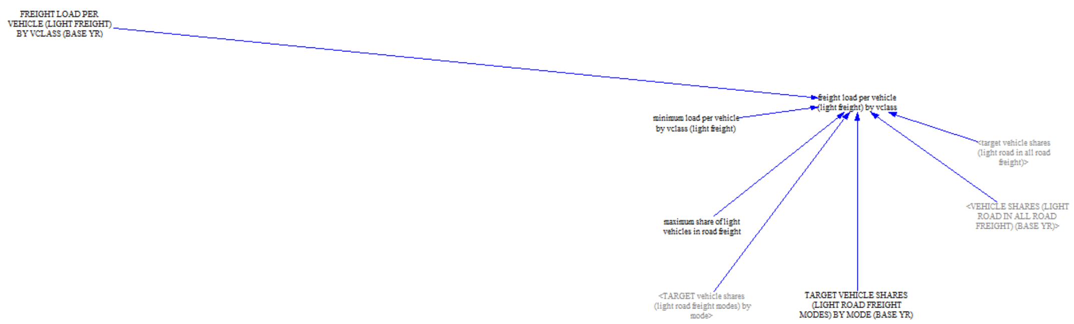

The equation below illustrates the calculation of the "LOAD PER VEHICLE BY VCLASS (OVER TIME)" on the basis of the share of light-freight vehicle by mode:

$$Load\ per\ vehicle\ by\ vclass\ (over\ time) =$$
$$= Load\ by\ class\ (BY) + \left(\frac{Min.load\ by\ vclass - Load\ by\ vclass\ (BY)}{Max.share\ by\ mode - Share\ by\ mode\ (BY)}\right) \times (Share\ by\ mode - Share\ by\ mode\ (BY))$$

The share of vehicles by light-freight mode in total road freight results from the product between the share of light vehicles in total road freight (main output of the view "demand (light road freight veh shares)") and the exogenous input on modal shares within the total freight vehicles distributing it across the light-freight modes.

Figure 28.6 shows the variables used for the calculation of the load per vehicle by vehicle class on the basis of the parameters required for the linear estimation.

Figure 28.6 Load per vehicle in light-freight as function of the vehicle shares by mode in total road freight



### *Annual km per freight vehicle by vehicle class*

The variable in the centre of the view, "FREIGHT LOAD PER VEHICLE BY VCLASS", gathers the information concerning the large- and light-freight services in a single set (matrix) of parameters.

The load per vehicle in case of non-motorized transport and pipelines is assumed to remain constant at the base year value.