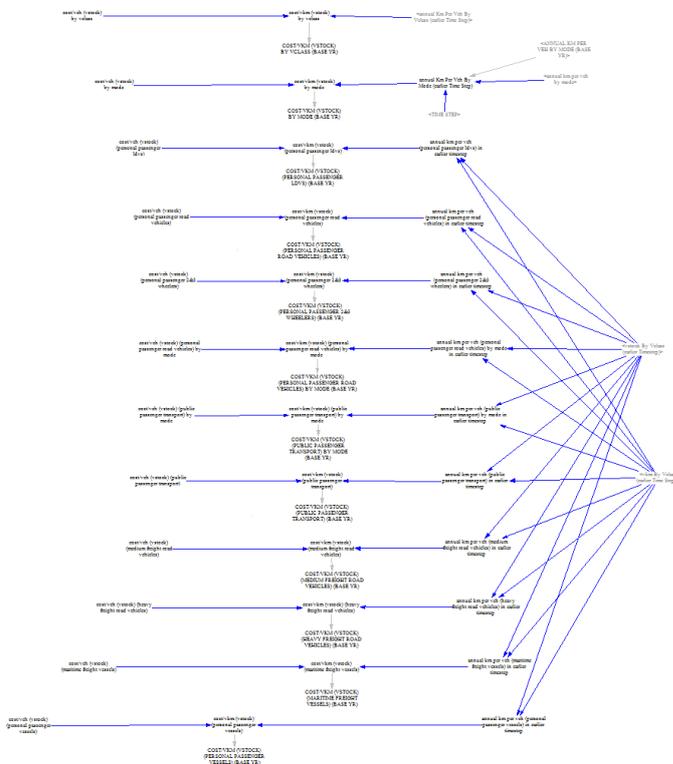


vehicle per year and the annual travel per vehicle lead to the outputs on vehicle cost per vkm. The latter is the set of variables located in the central column of the view.

Figure 24.2 Cost per vkm - Vensim sketch



Detailed description of the view

Inputs

The variable "COST/VEH BY PWTRN" comes from the view "vehicle cost (input)" and gathers the user inputs on the purchase price of newly registered vehicles over time. This variable represents the cost of vehicles with age equal to zero.

In each time step, the values stored here are displaced in a way that allows storing the correct purchase price in each of the "earlier" age subscripents (Figure 24.3 shows how the cost per vehicle by age is obtained in Vensim).

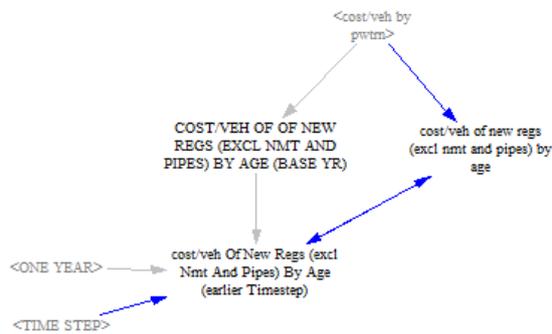
If the time step is 1, the following line illustrates what happens:

ZERO → "cost/veh by pwtrn", I → previous ZERO, II → previous I, ...

If the time step is a fraction of 1, linearly interpolated data are used in the different age subscripents.

For simplicity (and in order to avoid excessive input burdens on the user), the cost of the vehicles sold before the base year is assumed to be the same as for those registered at the base year. As a result, the cost of the vehicles in the initial stock is the same within each powertrain independently of the age.

Figure 24.3 Cost per vehicle by age



The data on the vehicle stock are evaluated in the view "vehicles by age" and are used here to calculate vehicle shares.

The average vehicle life by vehicle class is a variable calculated in the view "vehicles, new registrations (historical)". It is used here to estimate the annual vehicle cost, taking into account the average amount of years during which the vehicle is operational.

The vkm by vehicle class comes from the view "activity, loads and stock aggregates". It is necessary, along with the vehicle stock by vehicle class, to calculate the annual travel per vehicle at different levels of disaggregation.

The average annual travel, disaggregated by vehicle class or by mode, is directly available from the views "travel per vehicle" and "activity, loads and stock aggregates".

Since Vensim does not handle easily iterative calculations for data changing simultaneously over the same time step, data on the vehicle stock, vkm and annual travel per vehicle are delayed a time step. This is needed because the vehicle activity (vkm) and the annual travel per vehicle (equal to vkm divided by the vehicle stock) depend on the evolution of the cost of driving.

Outputs

Annual cost per vehicle

The aggregation of the cost per vehicle across vehicle classes and/or modes is always achieved through averaging the cost across the relevant subscripts and weighting by the corresponding vehicle shares. The cost per vehicle is divided by the average vehicle life to distribute the purchase cost along the years until the vehicle is expected to be scrapped.

$$\text{Annual Cost per vehicle} = \frac{\text{Cost per vehicle}}{\text{Average vehicle life}}$$

When this calculation is performed at a lower level of disaggregation than by vehicle class, then aggregated values of the average vehicle life are used. The weights used for this purpose correspond to the vehicle shares in the fleet.

The outputs on then annual cost per vehicle are calculated on the basis of input on the cost per vehicle by age, the average vehicle life, and the vehicle shares in the fleet.

Annual cost per vehicle by powertrain

$$\begin{aligned} \text{Annual cost per veh by powertrain} &= \frac{\sum_{\text{ages}} \text{Cost per veh by age} \times \text{Shares by age for each pwtrn}}{\text{average vehicle life by vclass}} = \\ &= \frac{\sum_{\text{ages}} \text{Cost per veh by age} \times \frac{\text{vstock by age}}{\text{vstock by powertrain}}}{\text{average vehicle life by vclass}} \end{aligned}$$

Annual cost per vehicle by vehicle class

$$\begin{aligned} \text{Annual cost per veh by vclass} &= \frac{\sum_{\text{pwtrns}} \text{Cost per veh by pwtrn} \times \text{Shares by pwtrn for each vclass}}{\text{average vehicle life by vclass}} = \\ &= \frac{\sum_{\text{powertrains}} \text{Cost per veh by powertrain} \times \frac{\text{vstock by powertrain}}{\text{vstock by vclass}}}{\text{average vehicle life by vclass}} \end{aligned}$$

Annual cost per vehicle by mode

$$\begin{aligned} \text{Annual cost per veh by mode} &= \frac{\sum_{\text{vclasses}} \text{Cost per veh by vclass} \times \text{Shares by vclass for each mode}}{\text{average vehicle life by mode}} = \\ &= \frac{\sum_{\text{vclasses}} \text{Cost per veh by vclass} \times \frac{\text{vstock by vclass}}{\text{vstock by mode}}}{\sum_{\text{vclasses}} \text{average vehicle life by vclass} \times \frac{\text{vstock by vclass}}{\text{vstock by mode}}} \end{aligned}$$

Annual cost per vehicle for personal passenger LDVS

$$\begin{aligned} \text{Annual cost/veh per. pas. LDVS} &= \frac{\sum_{\text{per. pas. LDVS vclass}} \text{Cost/veh by vclass} \times \text{Shares by vclass in per. pas. LDVS}}{\text{average vehicle life for personal passenger LDVS}} = \\ &= \frac{\sum_{\text{vclasses A to D}} \text{Cost per veh by vclass}[\text{PASSENGER, LDVS}] \times \frac{\text{vstock by vclass}[\text{PASSENGER, LDVS}]}{\text{vstock in total personal passenger LDVS}}}{\sum_{\text{vclasses A to D}} \text{average vehicle life by vclass}[\text{PASSENGER, LDVS}] \times \frac{\text{vstock by vclass}[\text{PASSENGER, LDVS}]}{\text{vstock in total personal passenger LDVS}}} \end{aligned}$$

Annual cost per vehicle for personal passenger road vehicles

$$\begin{aligned} \text{Annual cost/veh per. pas. road} &= \frac{\sum_{\text{per. pas. road vclass}} \text{Cost/veh by vclass} \times \text{Shares by vclass in per. pas. road}}{\text{average vehicle life for personal passenger road vehicles}} = \\ &= \frac{\sum_{\text{2\&3wheelers,ldvs}} \sum_{\text{vclasses a to d}} \text{Cost per veh by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total per. pas. road}}}{\sum_{\text{2\&3wheelers,ldvs}} \sum_{\text{vclasses a to d}} \text{average veh life by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total per. pas. road}}} \end{aligned}$$

Annual cost per vehicle for personal passenger TWO and THREE WHEELERS

$$\begin{aligned} \text{Annual cost/veh per. pas. 2\&3} &= \frac{\sum_{\text{per. pas. 2\&3 vclass}} \text{Cost/veh by vclass} \times \text{Shares by vclass in pers. pas. 2\&3}}{\text{average vehicle life for personal passenger two and three wheelers}} = \\ &= \frac{\sum_{\text{2\&3wheelers}} \sum_{\text{vclasses a to d}} \text{Cost per veh by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total per. pas. 2\&3 wheelers}}}{\sum_{\text{2\&3wheelers}} \sum_{\text{vclasses a to d}} \text{average veh life by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total per. pas. 2\&3 wheelers}}} \end{aligned}$$

Annual cost per vehicle by mode (TWO WHEELERS, THREE WHEELERS, LDVS) for personal passenger road vehicles

$$\begin{aligned} \text{Ann. cost/veh by mode for per. pas. road} &= \frac{\sum_{\text{per.pas. vclass}} \text{Cost/veh by vclass} \times \text{Shares by vclass in per. pas.}}{\text{average vehicle life for personal passenger road vehicles}} = \\ &= \frac{\sum_{\text{vclasses a to d}} \text{Cost per veh by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total pers. pas. vehicles in the mode}}}{\sum_{\text{vclasses a to d}} \text{average vehicle life by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total pers. pas. vehicles in the mode}}} \end{aligned}$$

Annual cost per vehicle by mode for public passenger transport

In case of TWO WHEELERS, THREE WHEELERS, LDVS and VESSELS

$$\begin{aligned} \text{Ann. cost/veh by mode for pub. pas.} &= \frac{\sum_{\text{pub.pas.vclass}} \text{Cost/veh by vclass} \times \text{Shares by vclass in pub. pas.}}{\text{average vehicle life for public passenger transport vehicles}} = \\ &= \frac{\sum_{\text{vclasses e and f}} \text{Cost per veh by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total pub. pas. trans. veh in the mode}}}{\sum_{\text{vclasses e and f}} \text{average vehicle life by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in total pub. pas. trans. veh in the mode}}} \end{aligned}$$

In case of LARGE ROAD and RAIL

$$\begin{aligned} \text{Ann. cost/veh by mode for pub. pas.} &= \frac{\sum_{\text{pub.pas.vclass}} \text{Cost/veh by vclass} \times \text{Shares by vclass in pub. pas.}}{\text{average vehicle life for public passenger transport vehicles}} = \\ &= \frac{\sum_{\text{vclasses}} \text{Cost per veh by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in the mode} [\text{PASSENGER}]}}{\sum_{\text{vclasses}} \text{average vehicle life by vclass}[\text{PASSENGER}] \times \frac{\text{vstock by vclass}[\text{PASSENGER}]}{\text{vstock in the mode} [\text{PASSENGER}]}} \end{aligned}$$

Annual cost per vehicle for public passenger transport

$$\begin{aligned} \text{Ann. cost/veh for pub. pas. trans.} &= \frac{\sum_{\text{pub.pas.vclasses}} \text{Cost/veh by vclass} \times \text{Shares by vclass in pub. pas.}}{\text{average vehicle life for public passenger transport vehicles}} = \\ &= \frac{\sum_{2\&3 \text{ wheelers, ldvs, vessels, large road, rail}} \sum_{\text{pub.pas.vclass}} \text{Cost per veh by vclass} \times \frac{\text{vstock by vclass}}{\text{vstock in total pub. pas. trans.}}}{\sum_{2\&3 \text{ wheelers, ldvs, vessels, large road, rail}} \sum_{\text{pub.pas.vclass}} \text{average veh life by vclass} \times \frac{\text{vstock by vclass}}{\text{vstock in total pub. pas. trans.}}} \end{aligned}$$

Annual cost per vehicle for medium freight road vehicles

$$\begin{aligned} \text{Ann. cost/veh for med.} &= \frac{\sum_{\text{med.fre.large road vclasses}} \text{Cost/veh by class} \times \text{Shares by class in med. LARGE ROAD}}{\text{average vehicle life for medium freight road vehicles}} = \\ &= \frac{\sum_{\text{vclasses A to C}} \text{Cost per veh by vclass}[\text{FREIGHT, LARGE ROAD}] \times \frac{\text{vstock by vclass}[\text{FREIGHT, LARGE ROAD}]}{\text{vstock in total med. freight LARGE ROAD}}}{\sum_{\text{vclasses A to C}} \text{average veh life by vclass}[\text{FREIGHT, LARGE ROAD}] \times \frac{\text{vstock by vclass}[\text{FREIGHT, LARGE ROAD}]}{\text{vstock in total med. freight LARGE ROAD}}} \end{aligned}$$

Annual cost per vehicle for heavy freight road vehicles

$$\begin{aligned} \text{Ann. cost/veh for heavy} &= \frac{\sum_{\text{heavy large road vclasses}} \text{Cost/veh by class} \times \text{Shares by class in heavy LARGE ROAD}}{\text{average vehicle life for heavy freight road vehicles}} = \\ &= \frac{\sum_{\text{vclasses d to f}} \text{Cost per veh by vclass}[\text{FREIGHT, LARGE ROAD}] \times \frac{\text{vstock by vclass}[\text{FREIGHT, LARGE ROAD}]}{\text{vstock in total med. freight LARGE ROAD}}}{\sum_{\text{vclasses d to f}} \text{average veh life by class}[\text{FREIGHT, LARGE ROAD}] \times \frac{\text{vstock by class}[\text{FREIGHT, LARGE ROAD}]}{\text{vstock in total heavy freight LARGE ROAD}}} \end{aligned}$$

Annual cost per vehicle for maritime freight VESSELS

$$\begin{aligned} \text{Ann. cost/veh for maritime} &= \frac{\sum_{\text{freight maritime vclasses}} \text{Cost/veh by class} \times \text{Shares by class in freig. maritime}}{\text{average vehicle life for maritime freight vessels}} = \\ &= \frac{\sum_{\text{vclasses c to f}} \text{Cost per veh by vclass}[\text{FREIGHT, VESSELS}] \times \frac{\text{vstock by vclass}[\text{FREIGHT, VESSELS}]}{\text{vstock in total maritime freight VESSELS}}}{\sum_{\text{vclasses c to f}} \text{average veh life by class}[\text{FREIGHT, VESSELS}] \times \frac{\text{vstock by class}[\text{FREIGHT, VESSELS}]}{\text{vstock in total maritime freight VESSELS}}} \end{aligned}$$

Annual cost per vehicle for personal passenger VESSELS

$$\begin{aligned} \text{Ann. cost/veh for per. VESSELS} &= \frac{\sum_{\text{per.pas.vess.vclass}} \text{Cost/veh by vclass} \times \text{Shares by class in per. pas. VESSELS}}{\text{average vehicle life for personal passenger VESSELS}} = \\ &= \frac{\sum_{\text{vclasses a to d}} \text{Cost per veh by vclass}[\text{PASSENGER, VESSELS}] \times \frac{\text{vstock by vclass}[\text{PASSENGER, VESSELS}]}{\text{vstock in total per. pas. VESSELS}}}{\sum_{\text{vclasses a to d}} \text{average veh life by vclass}[\text{PASSENGER, VESSELS}] \times \frac{\text{vstock by vclass}[\text{PASSENGER, VESSELS}]}{\text{vstock in total per. pas. VESSELS}}} \end{aligned}$$

Annual travel per vehicle

The annual travel per vehicle by vehicle class and disaggregated only by mode both variables are available inputs. All the aggregates concerning the average travel per vehicle are obtained by from the definition reported in the following equation.

$$\text{Annual travel per vehicle (output)} = \frac{\text{vkm (input)}}{\text{number of vehicles in the stock (input)}}$$

Numerator and denominator are available inputs at the vehicle class level. They can be aggregated at any level of detail summing up across subscripts. The calculation is reproduced several times in order to get all the aggregates necessary to be coupled with the outputs on annual cost per vehicle. The aggregates calculated are coherent with the definition of the modes and sub-modes considered, as detailed in the earlier section. The whole column of variables on the right side of the view results by the ratio of vehicle activity (vkm) and the vehicle stock at different levels of aggregation.

Cost per vkm

The annual cost per vehicle divided by the annual travel per vehicle leads to the cost per vkm:

$$\text{Cost per vkm} = \frac{\text{Annual cost per vehicle (USD/vehicle} \times \text{year)}}{\text{Annual travel per vehicle (km/year)}}$$

The central column of variables of this view ("COST/VKM (VSTOCK) ...") results from the application of this equation, using the information on the annual cost per vehicle and the annual travel per vehicle calculated earlier. The initial value of the variables is allocated to another variable to store the costs at the base year separately.

The outputs on cost per vkm are used in the view "cost of driving".