19. Travel per vehicle (passenger)

Overview

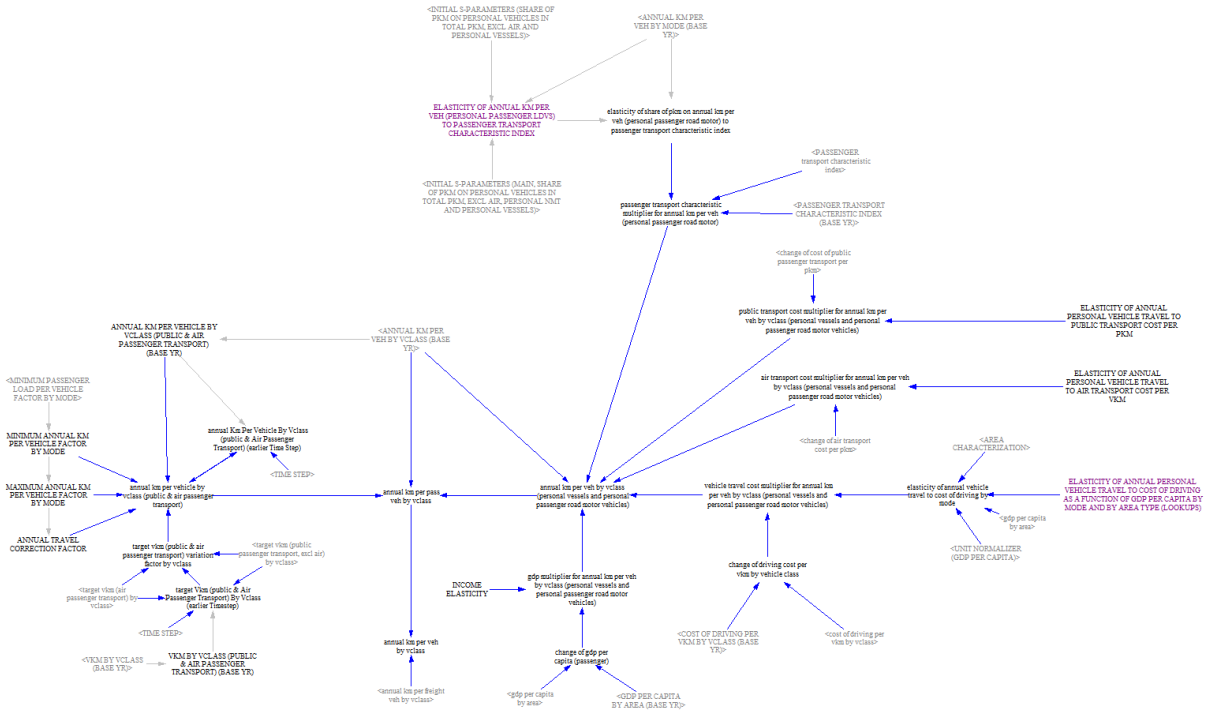
Target

The view aims to estimate the annual travel of passenger vehicles. The starting point is the user input on annual travel per vehicle by vehicle class at the base year, while the evolution over time is determined according to several factors, including the passenger transport characteristic index, macroeconomic parameters and the cost of driving.

Structure

A general idea of the appearance of the view is reported in Figure 19.1. Annual vehicle travel of passenger vehicles is approached considering personal vehicles separately from public transport and air transport vehicles.

Figure 19.1 Vensim sketch of the view



The calculations on personal vehicles are located on the right section of the view (Figure 19.2), while public transport and air transport vehicles are considered on the left (Figure 19.3).

Figure 19.2 Vensim sketch: focus on personal vehicles

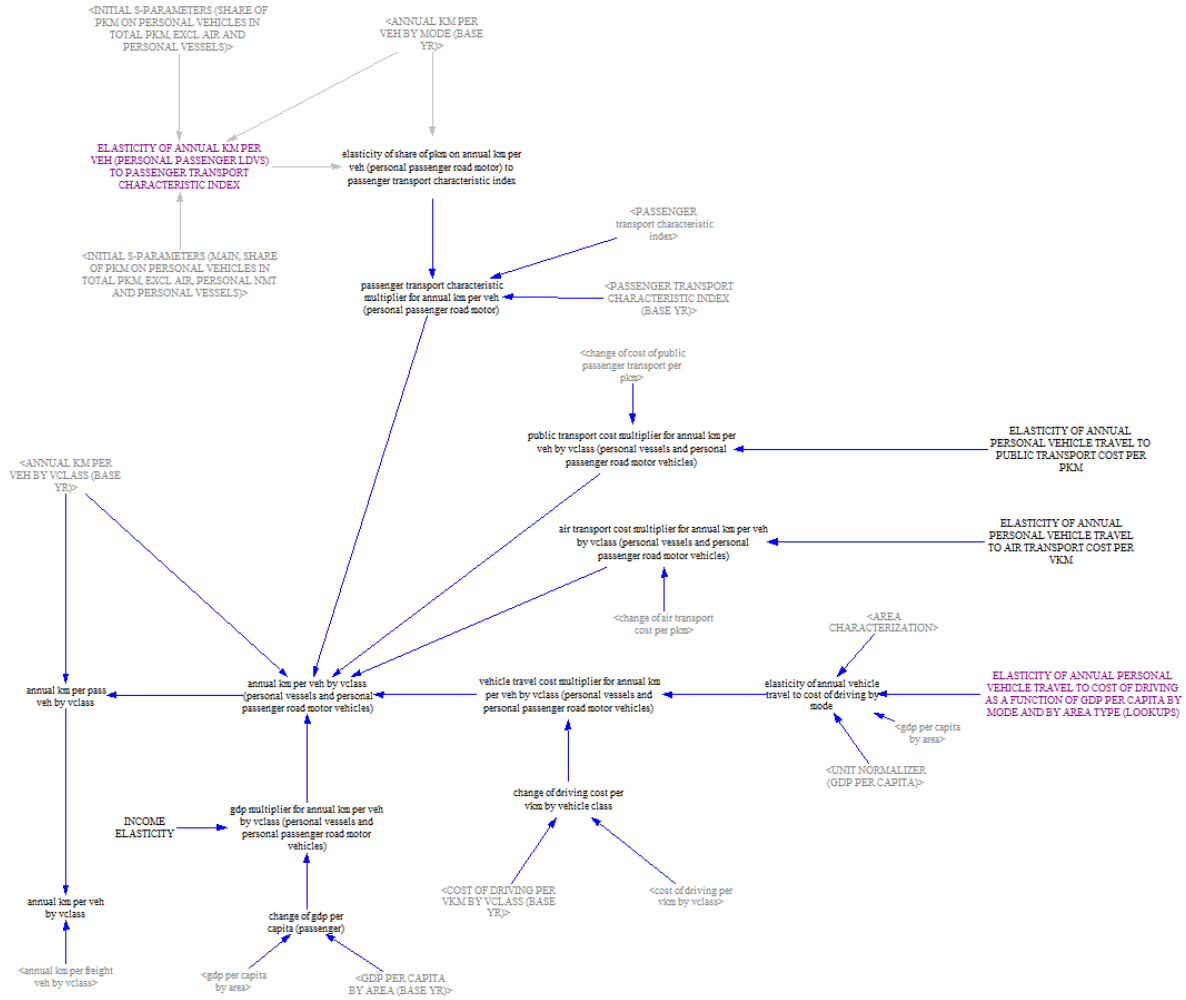
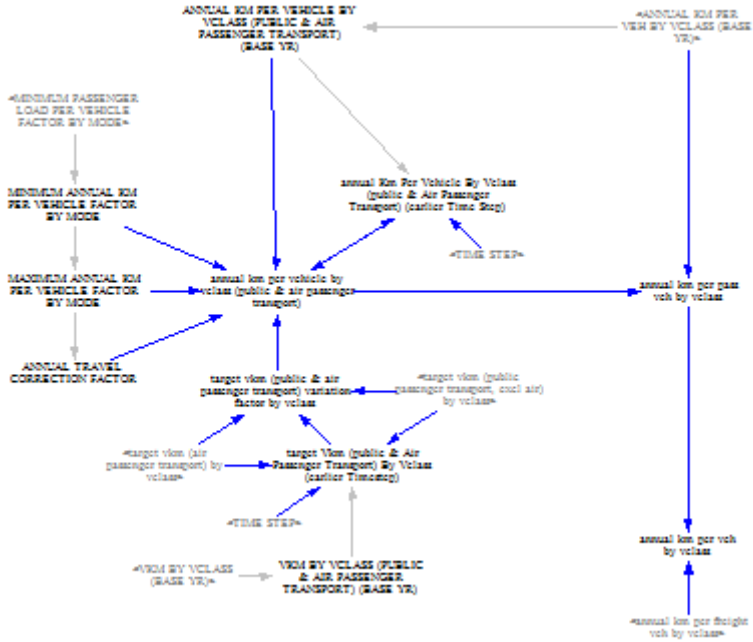


Figure 19.3 Vensim sketch: focus on public transport and air transport



Detailed description of the view

Inputs and general calculation flow

The variable "ANNUAL KM PER VEH BY VCLASS (BASE YR)" contains the input (possibly detailed by area, service, mode and vehicle class) on the average annual travel per vehicle at the base year introduced by the user in the ForFITS Excel file ("User inputs (BASE Y)" tab).

The evolution of annual travel per vehicle over time is treated in a different way for personal vehicles and for air and public transport. The two approaches are described in detail in the following sections.

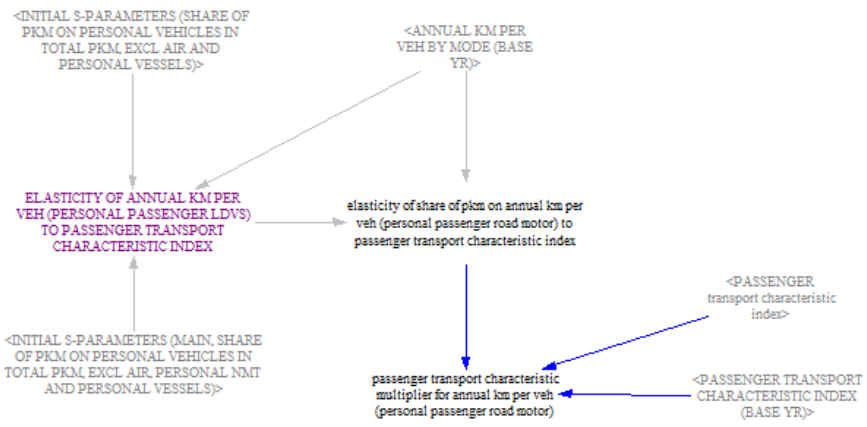
Personal vehicles

The factors influencing the annual travel of personal vehicles include the passenger transport characteristic index, macroeconomic parameters, and the cost of driving. In the future, this may be complemented by the consideration of the effect of changing the average travel speed on average vehicle travel, to reflect the fact that, historically, improvements of travel speed have been translated into increments of distance rather than in travel time savings (Crozet, 2005 and Litman, 2011).

The effect of each of these factors currently taken into account is explained individually in the following section, as well as related information concerning the elasticities through which they are taken into account.

Passenger transport characteristic index

Figure 19.4 **Vensim sketch: focus on the passenger transport characteristic index**



As explained in the "demand (passenger, main drivers)" view, the passenger transport characteristic index is related to the S-Curve defining the share of pkm on private vehicles (in particular, it is defined as 1 minus the asymptotic value –SCURVE parameter A – of the share of pkm on private vehicles curve). The index reflects the characteristics of transport systems, providing a numerical indication on the importance given to the use of private vehicles rather than public transport for passenger mobility.

The impact on the annual travel of personal vehicles of the passenger transport characteristic index is mainly due to the tendency to observe higher values of the average travel per personal passenger vehicle in regions with low population densities (such as rural areas and horizontally developed

urban agglomerations) and/or in regions where fuel taxation tends to be lower than the global average.

For these reasons, the evaluation of elasticity if the annual travel of personal light duty vehicles to the passenger transport characteristic index takes into account for an average annual travel of 20 000 km/year when the transport characteristic index is close to zero (i.e. for values similar to those observed in cities located in the United States, also used to characterize the HIGH guideline curve of the share of pkm on personal vehicles) and for an average annual travel of 11 000 km/year when the transport characteristic index is close to 0.7 (i.e. for values comparable to the data characterizing some of the urban environments of densely populated European and Asian cities, also used to characterize the LOW guideline curve of the share of pkm on personal vehicles). The information used for this assessment benefit from information available in UITP, 2006 (cited by IEA, 2008) and by statistical information on the average vehicle travel from national and international statistical offices.

The equations actually used for the determination of the elasticity that links the annual travel per vehicle as function of the transport characteristic index are the following:

$$E = \frac{\Delta y}{\Delta x} \times \frac{x}{y} =$$
$$= \frac{20\,000 - 11\,000}{(1 - PAR.A\ HIGH\ SCURVE\ ) - (1 - PAR.A\ LOW\ SCURVE)}$$
$$\times \frac{1 - PAR.A\ MAIN\ SCURVE}{Annual\ km\ per\ vehicle\ at\ the\ base\ year}$$
$$= \frac{20\,000 - 11\,000}{PAR.A\ LOW\ SCURVE - PAR.A\ HIGH\ SCURVE} \times \frac{1 - PAR.A\ MAIN\ SCURVE}{Annual\ km\ per\ vehicle\ at\ the\ base\ year}$$

As explained earlier, the first part of the equation $\left(\frac{\Delta y}{\Delta x}\right)$ represents the change of the annual vehicle travel associated to a variation of the transport characteristic index. The second factor $\left(\frac{x}{y}\right)$ is the ratio between the values of the index and the average annual vehicle travel at the base year.

The $PAR.A\ LOW\ SCURVE$, $PAR.A\ MAIN\ SCURVE$ and $PAR.A\ HIGH\ SCURVE$ parameters used in the equations above refer to the asymptotic value of the S-Curve of the share of pkm on personal vehicles, i.e. to the value of the guiding curve that is complementary to the passenger transport characteristic index (more information on this last point are available in the description of the view "demand (passenger, main drivers)").

The average travel values of 20 000 km/year and 12 000 km/year refer exclusively to the average annual travel of passenger LDVs. As a result, the elasticity obtained from the equation is only valid for this mode. In the case of TWO and THREE WHEELERERS (i.e. the other personal vehicles for which the annual travel depends on the passenger transport characteristic index), the elasticity is estimated proportionally to the different magnitude of the average annual travel in comparison with LDVs:

$$E(TWO\ or\ THREE\ WHEELERS) =$$
$$= E(LDVS) \times \frac{Annual\ travel\ per\ vehicle\ at\ the\ base\ year\ (TWO\ or\ THREE\ WHEELERS)}{Annual\ travel\ per\ vehicle\ at\ the\ base\ year\ (LDVS)}$$

The calculation of the elasticity values allows evaluating the multiplier that affects the initial annual travel per vehicle according to the evolution of the transport characteristic index. This is determined as follows:

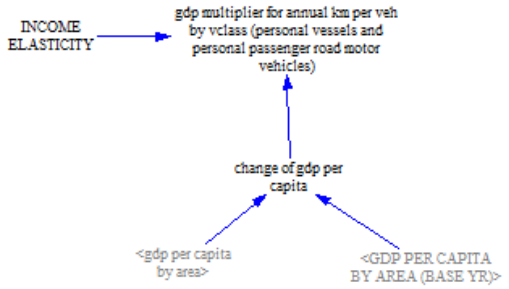
$$Passenger\ transport\ characteristic\ index\ multiplier = \\ = 1 + Percentage\ change\ on\ the\ index \times Elasticity\ of\ annual\ travel\ to\ the\ index$$

Where:

$$Percentage\ change\ on\ the\ index = \frac{Index\ (over\ time) - Index\ at\ the\ base\ year}{Index\ at\ the\ base\ year}$$

Macroeconomic parameters

Figure 19.5 Changes of annual travel of personal vehicles due to variations of GDP per capita: Vensim sketch



This section considers the impact on the annual travel of personal vehicles of changes on the GDP per capita. It considers that an increase of the incomes results in a slight increase of the annual travel per vehicle, while a reduction of the GDP per capita results in slightly lower average travel levels.

The macroeconomic parameters used as inputs are exogenous data introduced by the user ("Socio-economic data" tab of the ForFITS excel file), in combination with an elasticity parameter that modulates the extent to which a change in income modifies (in percent) the average annual travel per vehicle. In ForFITS, its value (for all personal vehicles) is set by default as 0.02. The elasticity of the mean driving distance (per car per year) suggested in literature ranges between -0.1 and 0.35 (Litman, 2011, citing Johansson and Schipper, 1997). The low value selected for ForFITS builds on the observation, in Johansson and Schipper, 1997, underlining that the values for this elasticity "is generally positive, although insignificant in some regressions".

The multiplier that implements the modifications of the initial annual travel per vehicle due to the effect of the GDP per capita is achieved according to the definition of elasticity:

$$GDP\ per\ capita\ multiplier = 1 + Percentage\ change\ on\ the\ GDP\ per\ capita \times Income\ elasticity$$

Cost of driving

In ForFITS, the cost of driving per vkm in any passenger mode (personal vehicles, public transport – including road, vessels and rail, and air transport) is assumed to influence vehicle ownership (this is addressed in the "demand (passenger, main drivers)" view), as well as the annual travel of personal vehicles. This view considers this last effect.

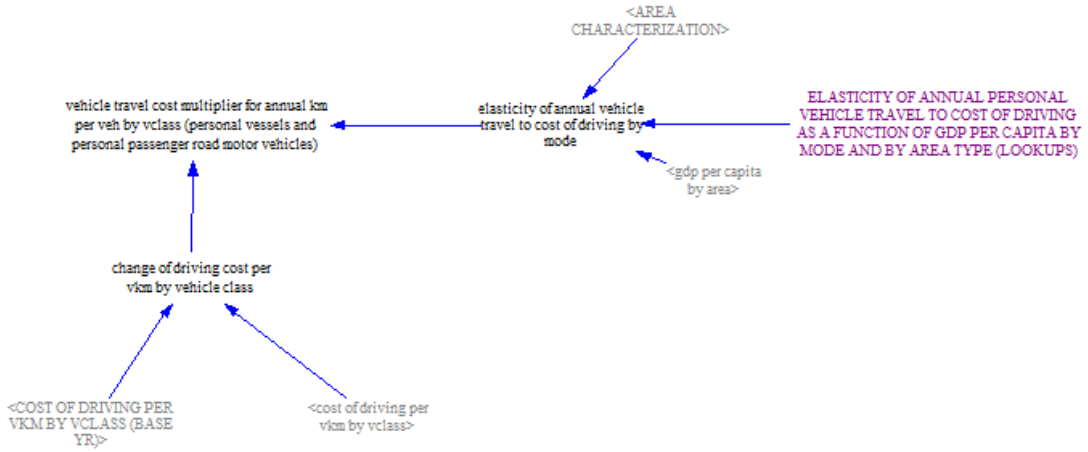
An increment of the cost of driving per vkm for personal vehicles is assumed to result in a reduction of the use of private vehicles. The direct elasticity linking cost variations and travel variations should therefore be always a negative number. The magnitude of the impact is assumed to depend on the current GDP per capita and on the area type (URBAN, NON-URBAN, GENERAL). The default assumptions used in ForFITS take into account are based on the idea that higher levels of GDP per capita are associated with a higher rigidity of the annual travel per vehicle, while the consequences of variations on the cost of driving at lower incomes are more significant. In respect of the area type, the annual travel is more sensitive to cost changes at the non-urban areas because in the urban ones normally travel distances are somewhat constrained by their very nature.

In ForFITS, the elasticities linking the cost of driving of personal vehicles to their average annual travel are expressed as function of the GDP per capita (in the "Socio-economic data" tab of the ForFITS Excel file) and of the area type characterized by the user (in the "Transport system (over time)" tab of the ForFITS Excel file). The default values of the elasticities were set on the basis of Litman, 2011 (suggesting a representative value of elasticity of average travel distance with respect to travel cost of -0.3). Elasticities are lower for higher incomes, and higher for lower incomes. The value emerging from literature was used for incomes in the range of 20 000-50 000 USD/year (i.e. for developed countries, where the literature sources are typically focused). For lower income areas, elasticities are progressively increased until a double value. For higher income elasticities are progressively reduced until a half of the literature value. Finally, the literature value was considered representative for non-urban demand. In the urban context distances of trips are frequently quite short and so there is less room for changes, also in relative terms. Hence, for urban demand half of the literature value was used.

The elasticities linking the cost of driving of personal vehicles to their average annual travel are also differentiated depending on the type of personal vehicle affected. The elasticities set for personal motorized road modes (TWO/THREE WHEELERS, LDVS) are assumed to be identical. For personal vessels, the annual travel per vehicle is assumed to be more rigid to reflect i) constraints affecting the travel patterns of personal boats used for professional aims (e.g. fishing); and ii) the lower sensitivity to price signals of high-income individuals using personal boats is for leisure.

The multiplier applied to the initial annual travel per vehicle is calculated according to the definition of elasticity and the percentage change of the cost of driving per vkm (Figure 19.6).

Figure 19.6 **Annual travel per vehicle on the basis of changes of the cost of driving: Vensim sketch**



The cross elasticities representing the influence of the cost of driving in the modes competing with personal vehicles (air and public transport) on the annual travel of personal vehicles are calculated endogenously on the basis of assumptions that characterize particular scenarios.

The changes of pkm on personal vehicles due to changes of air transport costs are evaluated under the hypothesis that the total pkm would remain constant:

$$pkm_{Air} + pkm_{Public} + pkm_{Personal} = new\ pkm_{Air} + new\ pkm_{Public} + new\ pkm_{Personal}$$

The impact caused on passenger travel in each modal option (personal vehicles, public transport, air transport) can be expressed through elasticities ($E_{travel\ change\ /cost\ change}$) that affect the initial value:

$$new\ pkm_{Air} + new\ pkm_{Public} + new\ pkm_{Personal} =$$
$$= pkm_{Air} \times \left(1 + \%_{change\ Air} \times E_{Air/Air}\right) + pkm_{Public} \times \left(1 + \%_{change\ \ Air} \times E_{Public/Air}\right)$$
$$+ pkm_{Personal} \times \left(1 + \%_{change\ Air} \times E_{Personal/Air}\right)$$

The $E_{Personal/Air}$ can be isolated, expressing it as a function of the elasticity of air travel to air travel cost ($E_{Air/Air}$), the elasticity of public transport travel to air travel cost ($E_{Public/Air}$), and pkm before the change of air travel cost:

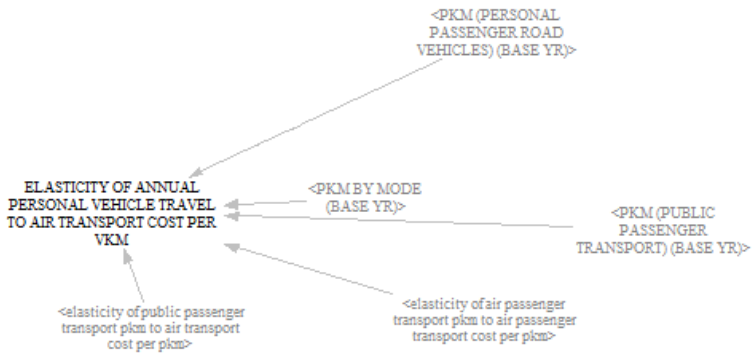
$$E_{Personal/Air} = \frac{-E_{Air/Air} \times pkm_{Air} - E_{Public/Air} \times pkm_{Public}}{pkm_{Personal}}$$

Taking into account that the elasticities $E_{Air/Air}$ and $E_{Public/Air}$ are exogenous inputs already introduced in the views "demand (passenger, public)" and "demand (passenger, air)" respectively, as well as considering the pkm at the base year split by mode from the view "activity, loads and stock aggregates", the equation above results, in Vensim, as shown in Figure 19.7.

The approach described here suggests that this cross-elasticity should affect pkm. It is applied to the annual travel considering that this is the component mainly absorbing the effect in personal vehicles

(since average loads on personal vehicles tend to have a low sensitivity to changes in the cost of driving, this effect has been neglected in ForFITS).

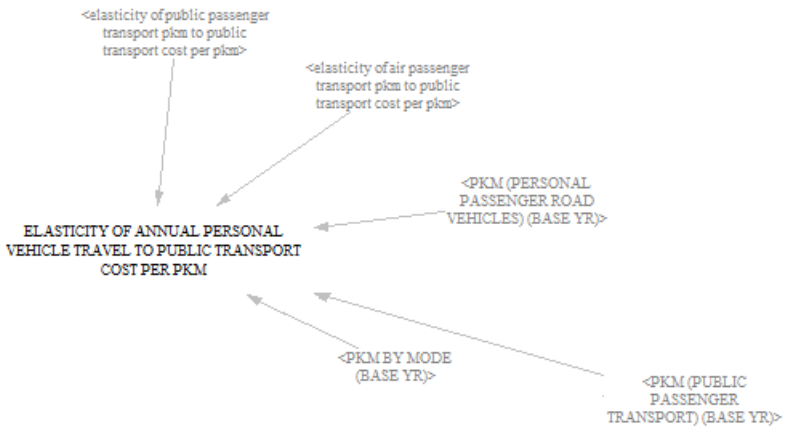
Figure 19.7 **Elasticity of annual personal vehicle travel to air transport cost: Vensim sketch**



The other cross elasticity, $E_{Personal/Public}$, (Figure 19.8) is calculated under the same overall hypothesis (constant total pkm), but assuming that the cause of the variation of pkm on personal vehicles, public transport and air transport is a change on the cost of driving in public transport:

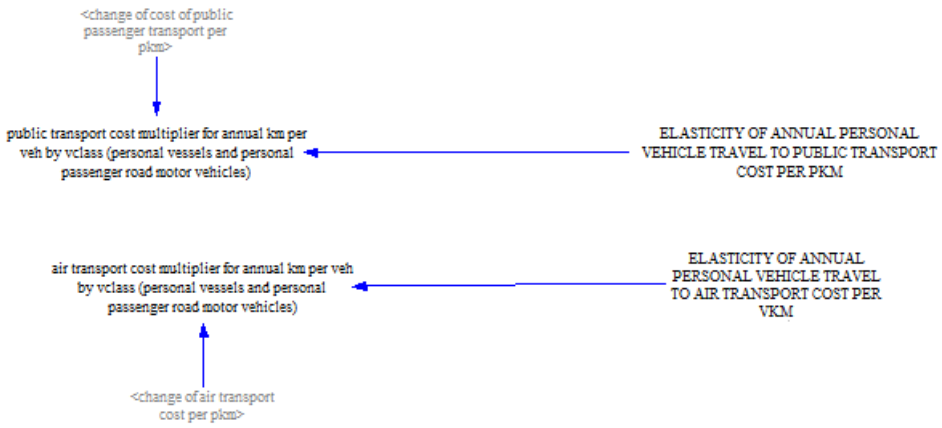
$$E_{Personal/Public} = \frac{-E_{Air/Public} \times pkm_{Air} - E_{Public/Public} \times pkm_{Public}}{pkm_{Personal}}$$

Figure 19.8 **Elasticity of annual personal vehicle travel to public transport cost: Vensim sketch**



The cross effects of changes in the cost of driving in public transport and air transport modes on the annual travel of personal vehicles are reflected by means of multipliers. As usual, such multipliers are defined on the basis of the elasticity and the percentage change of the relevant variable (Figure 19.9).

Figure 19.9 **Multipliers for cross effects of changes in the cost of driving in public transport and air transport modes on the annual travel of personal vehicles**



Air and public transport

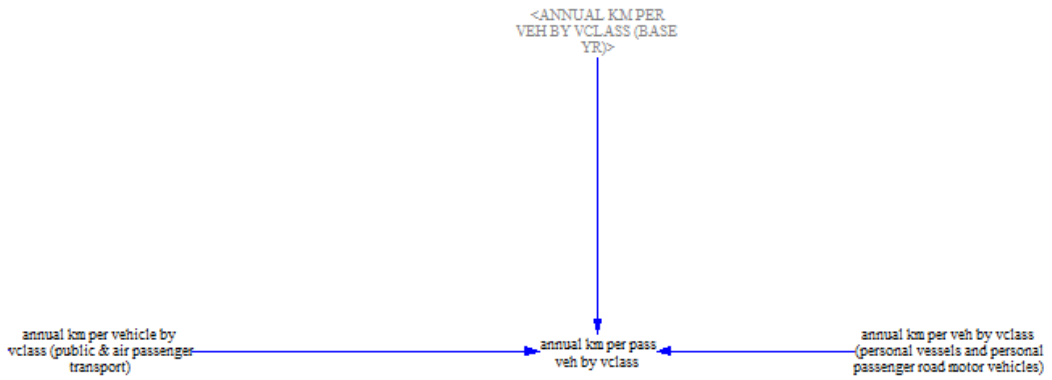
In case of air and public transport, the direct effects of a change of costs is applied to the pkm estimated in the relevant "demand" views for the respective groups of passenger vehicles and modes. The same views take into account how this pkm change is passed to vkm by also considering the effects on the load factor of the same types of passenger vehicles. For air and public transport, this view takes care of evaluating how the changes affecting vkm are passed to vkm and the vehicle stocks.

ForFITS has been conceived in a way that allows absorbing some of the vkm variation by changes in the annual travel per vehicle (Figure 19.3). Two factors limit the range in which the annual travel per vehicle can change, passing the variation of vkm to the vehicle stock only if the vkm change exceeds these limits. These minimum and maximum factors are currently set (by using exogenous inputs on the minimum load per vehicle) in a way that maintains the annual travel per vehicle over time for air and public transport is estimated constant. This allows avoiding step changes in the modelling results and means that the vkm variations are currently passed entirely to the vehicle stock. In the future, this part of ForFITS may be revised to improve the distribution of the vkm variation, so that it is partly absorbed by changes in the vehicle stock and partly resulting in changes to the average travel per vehicle.

Outputs

The main output of the view is the "ANNUAL KM PER PASS VEH BY VCLASS" variable. This contains the annual travel per vehicle for each area, mode and vehicle class. The variable is the result of gathering the calculations performed for personal passenger vehicles as well as for passenger air and public transport (Figure 19.10).

Figure 19.10 Annual km per passenger vehicle by vehicle class: Vensim sketch

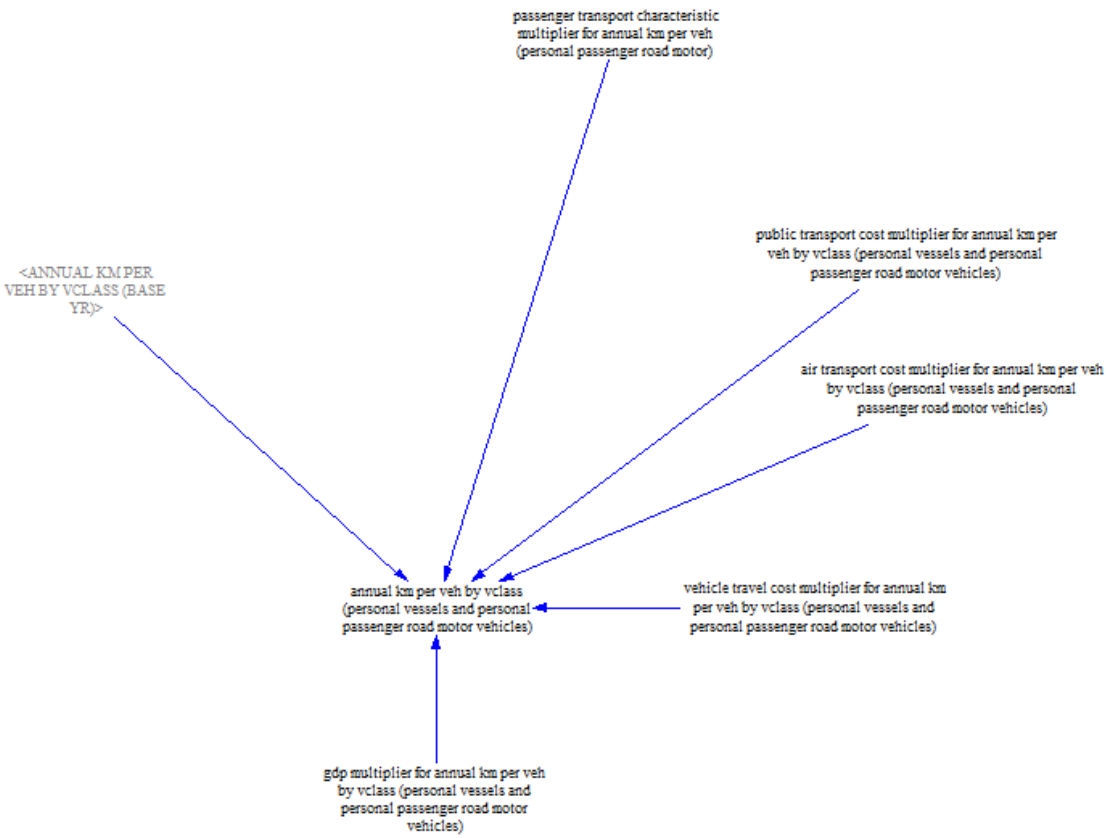


This output is used in the demand generation module to convert from each other to target vkm or target vehicle stock. The variable will then be split by powertrain and by age respectively in the views "travel per vehicle" and "travel per vehicle by age".

Personal vehicles

The annual travel per vehicle over time is calculated as the initial value affected by the multipliers concerning the different factors that impact on the variable (Figure 19.11).

Figure 19.11 Annual travel per personal passenger vehicle



In case of personal motorized road vehicles (vehicle classes A to D of the modes TWO WHEELERS, THREE WHEELERS and LDVS), the causes having an effect on the annual travel per vehicle are the GDP per capita, the transport characteristic index, the own cost of driving and the cost of public and air transport as competitors modes:

$$Annual\ travel\ per\ vehicle\ (over\ time) =$$
$$= Initial \times Index\ multiplier \times GDP/capita\ multplier \times Cost\ multipliers\ (cross\ and\ direct)$$

The transport characteristic index is only related to road transport and the cross elasticities link the air and public transport with only personal motor road vehicles. Therefore, the factors affecting the annual travel per vehicle in case of personal boats (vehicle classes A to D of VESSELS mode) are the GDP per capita and the own cost of driving:

$$Annual\ travel\ per\ vehicle\ (over\ time)$$
$$= Initial \times GDP/capita\ multplier \times Cost\ multiplier\ (direct)$$

In case of walking and biking (vehicle classes A and B of NON-MOTORISED TRANSPORT mode) the average annual travel is supposed to remain always constant.

Air and public transport

The annual travel per vehicle is calculated accordingly to its value at the earlier TIME STEP and the variation on the target vkm:

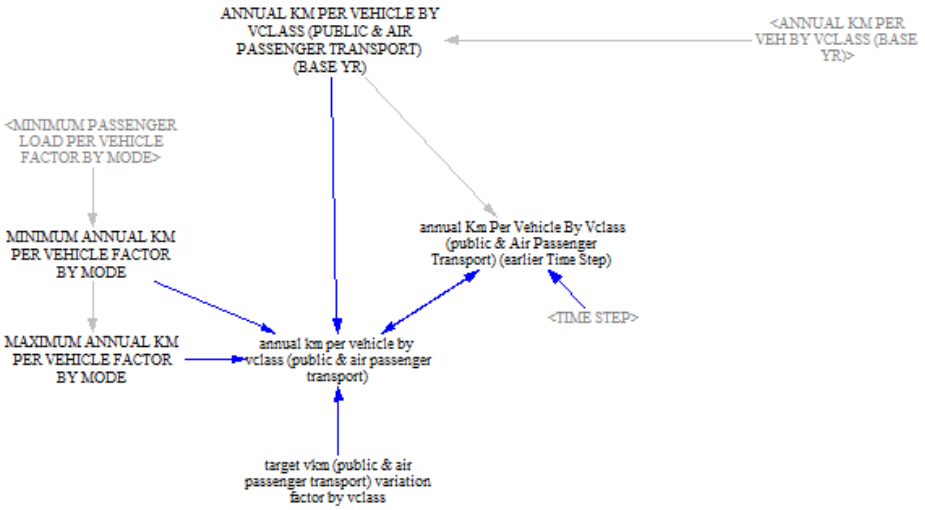
$$Travel\ per\ vehicle\ (over\ time) =$$
$$= \frac{Target\ vkm}{Target\ vkm\ at\ the\ earlier\ TIME\ STEP} \times Travel\ per\ vehicle\ at\ the\ earlier\ TIME\ STEP$$

When the result of the equation above falls out of the range set by the minimum and maximum factors multiplied by the initial annual travel per vehicle, then the value is corrected as follows (see also Figure 19.12):

$$If\ travel\ per\ vehicle\ > Maximum\ factor \times Annual\ travel\ per\ vehicle\ at\ the\ base\ year \rightarrow$$
$$\rightarrow Travel\ per\ vehicle = Annual\ travel\ per\ vehicle\ at\ the\ base\ year$$

$$If\ travel\ per\ vehicle\ < Minimum\ factor \times Annual\ travel\ per\ vehicle\ at\ the\ base\ year \rightarrow$$
$$\rightarrow Travel\ per\ vehicle = Minimum\ factor \times Annual\ travel\ per\ vehicle\ at\ the\ base\ year$$

Figure 19.12 Annual travel per vehicle for air and public transport: Vensim sketch



However, in order to avoid steps in the modelling results, the minimum passenger load per vehicle factor is currently set to 1 in all the modes. This means that both the maximum and minimum factors have a value of 1. Therefore, in the current version of ForFITS the annual travel per vehicle in case of air and public transport is estimated to remain always constant at the base year value. Changes in the target vkm are considered to have no effect on travel, being fully passes to the number of vehicles.

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