6. Demand (passenger, public)

Overview

Target

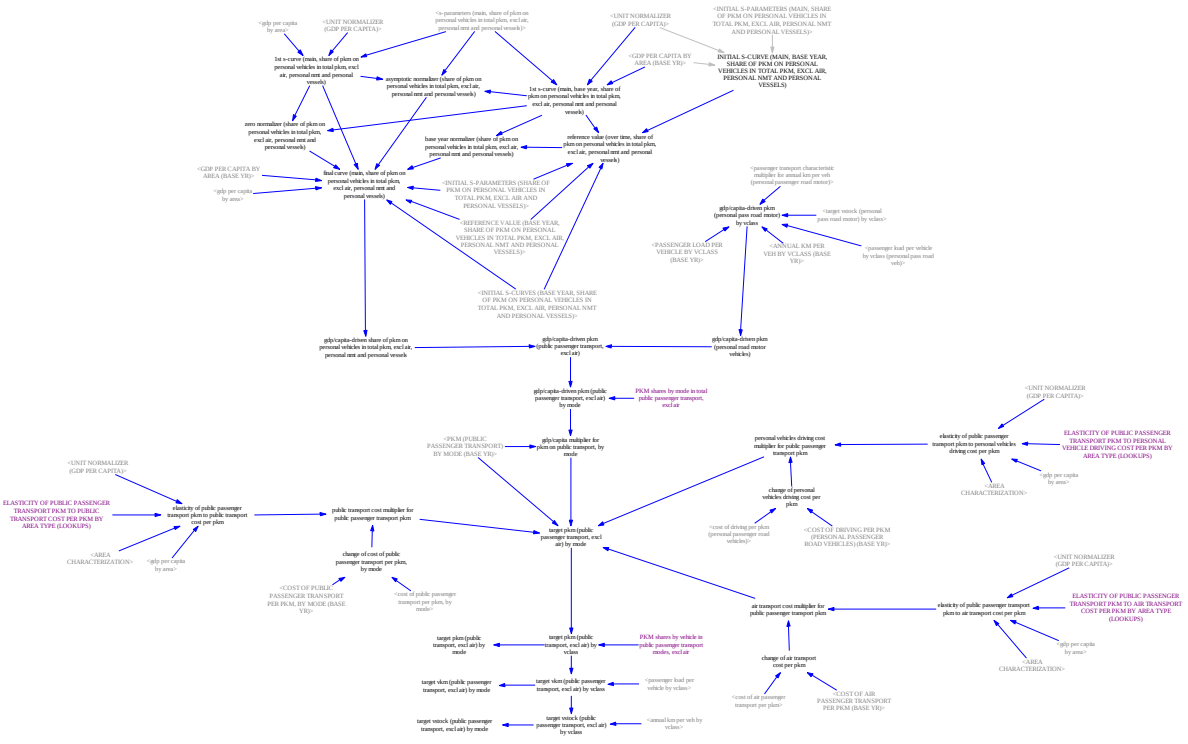
The "demand (passenger, public)" view generates the public transport demand as a function of time. It specifically estimates the target passenger travel (pkm), vehicle travel (vkm) and vehicle stock for collective passenger transport.

Exogenous data are: i) the share of public transport in total transport; and ii) pkm projections of personal passenger vehicles. With pkm, vkm are calculated taking into account the average travel per year of the vehicles. The target vehicle stock for public transport is deduced from vkm and the average vehicle load.

Structure

Figure 6.1 shows the whole set of variables used in the "demand (passenger, public)" view. The data that define the S-curves used to project the share of pkm on public transport modes are at the top part of the figure. The top section shows the calculations on defining of the pkm share of public transport drivers on the basis of changes in GDP per capita. The central variable is the key output: pkm on public passenger transport, excluding aviation, by mode. The vertical line of variables below it depicts the flow of calculations as the model moves from pkm to vkm and the vehicle stock. Modules on the right and left of this vertical axis contain information on the elasticities of pkm with respect to changes in the cost of driving of different "passenger transport driving modes" (air, public transport and personal vehicles).

Figure 6.1 Demand (passenger, public): Vensim sketch



Detailed description of the view

Understanding the "demand (passenger, public)" view necessitates a firm understanding of the passenger vehicles in each of their categories (See Table 6.1 for details). Specific vehicle classes within the modal definition used in ForFITS correspond to specific "passenger transport driving mode", highlighting transport on private/personal vehicles or on vehicles for public transport purposes (i.e. "map" of the modes and vehicle classes belonging to specific "passenger transport driving modes").

Table 6.1 Passenger / public modes and classes

Service: Passenger			
Modes	*Vehicle classes for private/personal vehicles*	*Vehicle classes for collective/public transport vehicles*	*Vehicle classes for both personal vehicles and public transport (total, in this view)*
NMT	A and B*	E and F	E and F
TWO WHEELERS	A to D	E and F	A to F
THREE WHEELERS	A to D	E and F	A to F
LDVS	A to D	E and F	A to F
VESSELS	A to D*	E and F	E and F
LARGE ROAD	Not applicable (only collective)	A to F	A to F
RAIL	Not applicable (only collective)	A to F	A to F
AIR	Air is excluded from this view		
PIPELINES	Not applicable (only freight)		

* Neglected in calculations on the share of pkm of public transport: these data are frequently unavailable in the statistical data on pkm.

Inputs and general calculation flow

Calculations for values resulting from changes in GDP per capita, as modified by the transport characteristic and environmental culture indexes

GDP per capita (as calculated in the view "economic parameters") is the main driver of the top section of this view (see Figure 6.2).

The four parameters contained in the variable "S-PARAMETERS (MAIN, SHARE OF PKM ON PERSONAL VEHICLES IN TOTAL PKM, EXCL AIR, PERSONAL NMT AND PERSONAL VESSELS)" (located at the top of the sketch, in the centre) define the "first S-curve" with the share of pkm on personal vehicles.

The top left of Figure 6.3 contains the "normalizing" parameters. They ensure that the final S-curve with the share of pkm on personal vehicles always intercepts the "reference value", i.e. the point defined by the share of pkm on personal vehicles and the GDP per capita, represented by the variable "REFERENCE VALUE (BASE YEAR, SHARE OF PKM ON PERSONAL VEHICLES IN TOTAL PKM, EXCL AIR, PERSONAL NMT AND PERSONAL VESSELS)". Initially, the "reference value" is characterized by the share of pkm on personal vehicles and the GDP per capita at the base year. In following time steps, it is updated (as calculated in "REFERENCE VALUE (OVER TIME, SHARE OF PKM ON PERSONAL VEHICLES IN TOTAL PKM, EXCL AIR, PERSONAL NMT AND VESSELS)") to reflect changes due to structural and behavioural variations.

Figure 6.2 Calculations concerning values driven by changes in GDP per capita: Vensim sketch

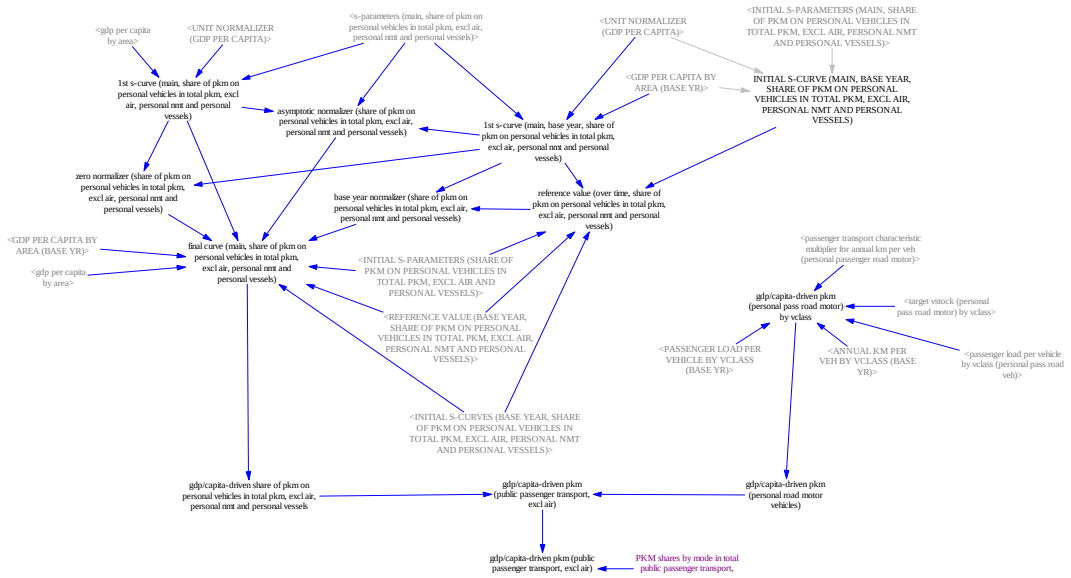
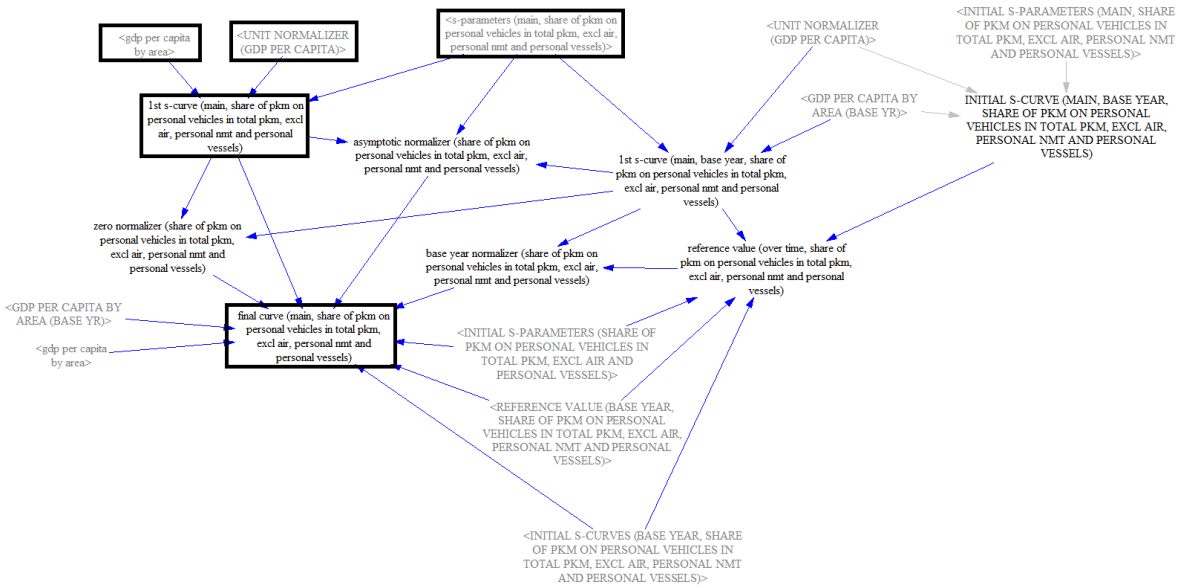


Figure 6.3 Determining the final S-curve on the share of pkm on personal vehicles (complementary to the share of pkm on public transport): Vensim sketch



When the share of personal vehicles pkm at the base year falls within the limits established by the HIGH and LOW guiding S-curves, the variable "FINAL CURVE (MAIN, SHARE OF PKM ON PERSONAL VEHICLES IN TOTAL PKM, EXCL AIR, PERSONAL NMT AND PERSONAL VESSELS)" equals "1ST S-CURVE (MAIN, SHARE OF PKM ON PERSONAL VEHICLES IN TOTAL PKM, EXCL AIR, PERSONAL NMT AND PERSONAL VESSELS)". This is the point corresponding to the GDP per capita at the time of calculation on the S-curve defined by the parameters "S-PARAMETERS (MAIN, SHARE OF PKM ON PERSONAL VEHICLES IN TOTAL PKM, EXCL AIR, PERSONAL NMT AND PERSONAL VESSELS)", as defined in the view "demand (passenger, main drivers)". In this case, only the variables identified by a square in Figure 6.3 are operational.

In other words:

- At TIME=INITIAL TIME
  Final S-Curve = First S-Curve = Initial S-Curve
  Final S-Curve contains the initial reference value (Figure 6.4).

- At TIME > INITIAL TIME
  Final S-Curve = First S-Curve, without applying any normalization
  The S-curve does not contain any longer the historical value if there were structural or behavioural changes (Figure 6.5).

Figure 6.4 **Share of pkm on personal vehicles (personal vehicles versus public transport, excluding air): base-year evaluation of the final S-curve when the share falls between the LOW and HIGH driving S-curve range**

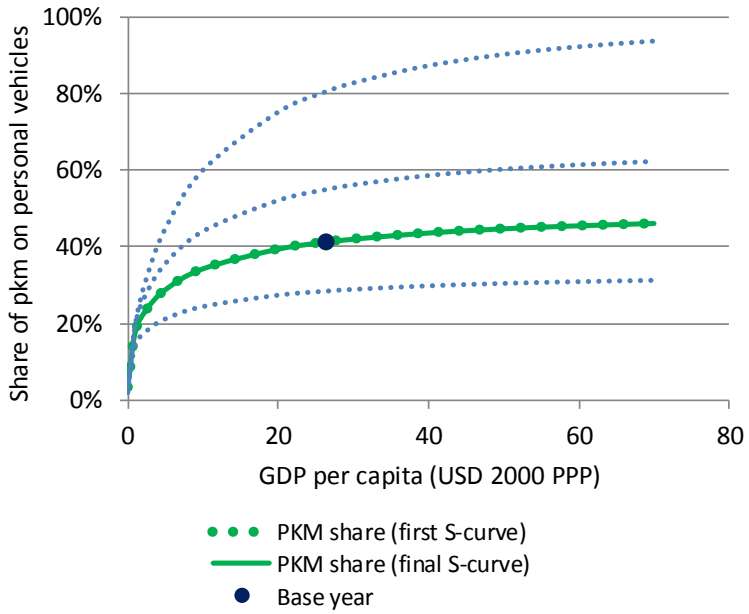
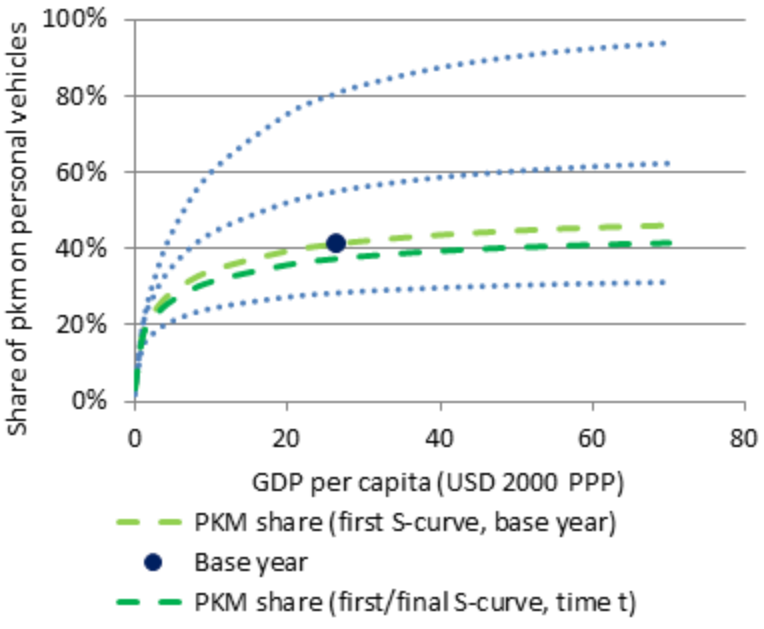
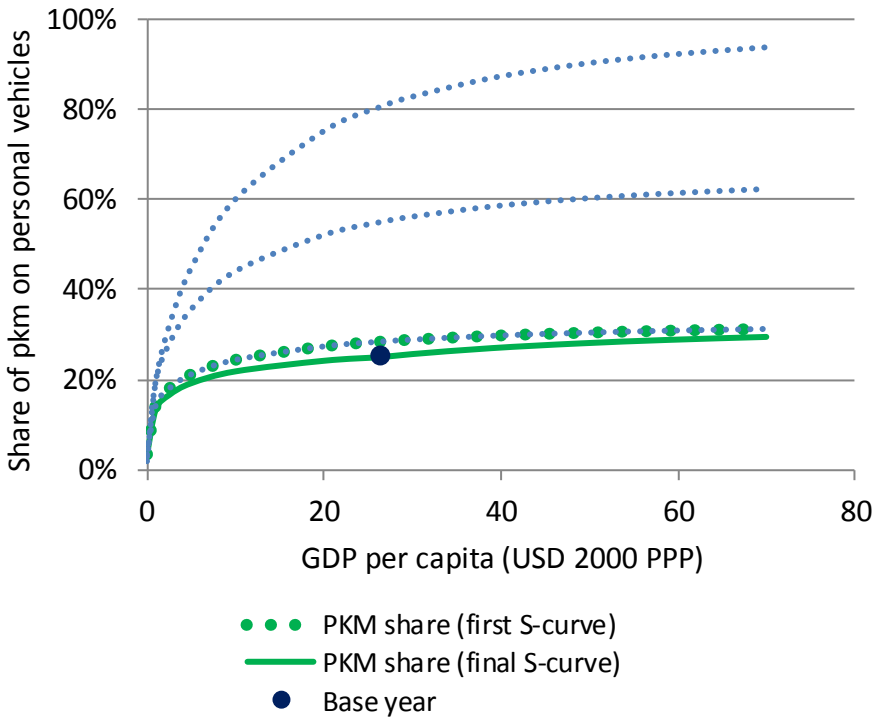


Figure 6.5 **Share of pkm on personal vehicles (personal vehicles versus public transport, excluding air): evaluation of the final S-curve when the share falls between the LOW and HIGH driving S-curves and factors such as the transport characteristic index change the first S-curve pattern over time**



The normalization phase is only required when the initial reference value falls beyond the range defined by the HIGH and LOW guiding S-curves. In this situation, the initial S-Curve calibrated in the view "demand (passenger, main drivers)" (equal to the first S-curve, in the base year) does not contain the point corresponding to the base year values, while the "normalized curve" (i.e. the final S-curve" does (Figure 6.6).

Figure 6.6 **Share of pkm on personal vehicles (personal vehicles versus public transport, excluding air): base-year evaluation of the final S-curve when the share is exterior to the LOW and HIGH driving S-curve range**



When the initial reference value falls beyond the range defined by the HIGH and LOW guiding S-curves, the normalizers are also always active over time:

- At TIME=INITIAL TIME
  The final S-Curve is defined interpolating with a weighted average based on the base year pkm share at the GDP per capita of the base year and the initial (or first) S-Curve at zero and infinity. This ensures the intersection of the base year reference value, as well as a progressive move towards the first S-Curve in zero and infinity (see Figure 6.6);

- At TIME>INITIAL TIME
  The final S-Curve is defined on the basis of the first S-Curve and an updated reference value. The first S-Curve, calculated in the view "demand (passenger, main drivers)", modifies the calibrated initial S-Curve taking into account of the changes of the passenger transport characteristic and environmental culture indexes over time.
  The updated reference value consists in the share of pkm on personal vehicles at the base year adjusted proportionally to the change of the first S-curve with respect to the initial S-curve.
  If the initial reference value falls below the LOW guiding S-curve, the updated reference value is calculated as follows:

$$Reference\ value\ (over\ time)$$
$$= Reference\ value_{GDP\ per\ capita\ (base\ year)}$$
$$+ \left(First\ S\ curve_{GDP\ per\ capita\ (base\ year)} - \ Inital\ S\ curve_{GDP\ per\ capita\ (base\ year)}\right)$$
$$* \frac{Reference\ value_{GDP\ per\ capita\ (base\ year)}}{Inital\ S\ curve_{GDP\ per\ capita\ (base\ year)}}$$

If the initial reference value falls above the HIGH guiding S-curve, the equation becomes:

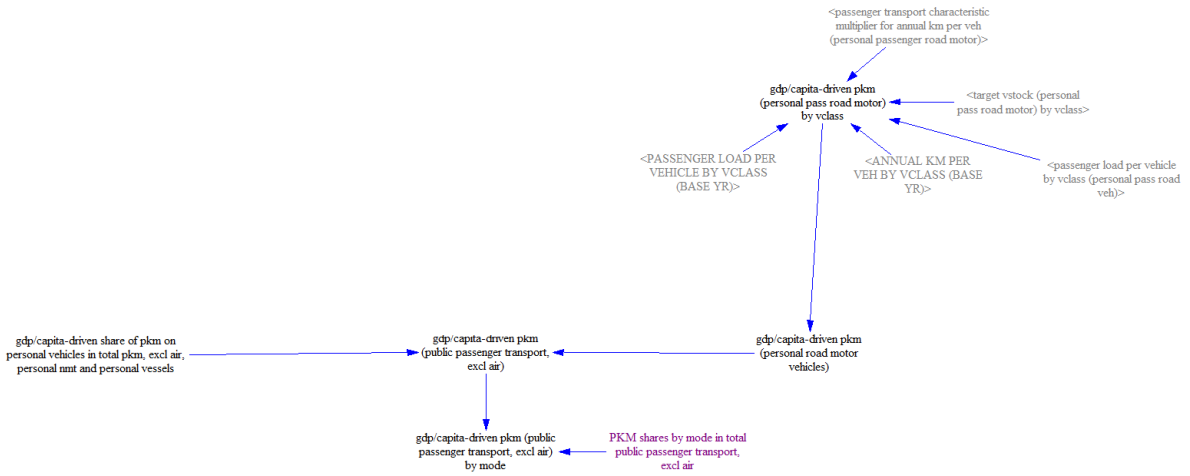
$$Reference\ value\ (over\ time)$$
$$= Reference\ value_{GDP\ per\ capita\ (base\ year)}$$
$$+ \left(First\ S\ curve_{GDP\ per\ capita\ (base\ year)} - \ Inital\ S\ curve_{GDP\ per\ capita\ (base\ year)}\right)$$
$$* \frac{Upper\ Ceiling\ of\ S\ curve\ families - Reference\ value_{GDP\ per\ capita\ (base\ year)}}{Upper\ Ceiling\ of\ S\ curve\ families - Inital\ S\ curve_{GDP\ per\ capita\ (base\ year)}}$$

The GDP per capita driven pkm on collective passenger transport vehicles by area are calculated with the share of pkm on personal vehicles complementary to the share of pkm on public transport) and the actual pkm on personal vehicles (calculated from the product of the target vehicle stock for personal vehicles, average annual travel and load[1]) in the same area (Figure 6.7):

$$pkm\ on\ collective\ vehicles = pkm\ on\ personal\ vehicles \times \frac{(1 - Share\ of\ pkm\ on\ personal\ vehicles)}{Share\ of\ pkm\ on\ personal\ vehciles}$$

The pkm over time on collective passenger transport vehicles are distributed across the modes by exogenous data. The value over time is compared to the base year value so as to obtain a multiplier that indicates the evolution of pkm on collective vehicles by mode due to the evolution of the GDP per capita (Figure 6.7).

Figure 6.7 Evaluation of GDP-driven pkm over time on collective passenger transport vehicles: Vensim sketch



[1] The target vehicle stock for personal vehicles is calculated in the "demand (pass. personal motor road)" view as a function of GDP per capita. As cost-related effects are taken into account at a later stage in the calculations, the average travel for personal vehicles used in this calculation refers to the base year. This simplification is justified because average travel for personal vehicles is not strongly affected by changes in GDP per capita. Load factors (also required for the GDP/capita driven pkm calculations) consider the changes in ownership occurring after the base year (see the description of the "load (passenger)" view for more details on the relationship between load factors and vehicle ownership on personal vehicles). This is also a simplification, since changes in the ownership of personal vehicles are not only driven by the variation of GDP per capita. This approach is justified by the fact that GDP per capita by far the main driver behind these changes (this need rephrasing as it seems contradictory at first glance).

"PKM (PUBLIC PASSENGER TRANSPORT) BY MODE (BASE YR)" compares the pkm on public transport over time and in the base year as a result of changing GDP per capita. The calculation aggregates across the pkm of the vehicle classes and modes contributing to public transport in the base year. The result is then used to evaluate the multiplier that, applied to base year pkm, introduces variations due to changes in GDP per capita.

Calculations on values driven by changes in the cost of driving

The evolution of the cost of driving in the public transport has effect on the amount of pkm on collective passenger transport vehicles (higher costs lead to a decline of the pkm), but also on the pkm of competing "driving passenger modes" (personal vehicles and air). This is explained by a cross-effect due to passengers having the potential to shift across available passenger modes. The variables on the cost of driving per pkm are endogenous inputs from the view "cost of driving" which calculates the three components defining the total cost: cost of vehicles, cost of fuel and cost of crew. Variations of the cost of driving per pkm always refer to the percentage of change compared to the initial base year value:

$$Change\ on\ cost\ of\ driving = \frac{Cost\ of\ driving\ (over\ time) - Cost\ of\ driving\ (base\ year)}{Cost\ of\ driving\ (base\ year)}$$

Elasticities that quantify the impact from changes of the cost of driving on the pkm on public transport vehicles are exogenous in ForFITS. The default elasticities were based on the elaboration of available information from scientific literature: for developed economies, the elasticity of public transport and pricing has been estimated by Litman (2011) ≈ -0.4; in the same average income conditions, the cross elasticity of public transport with respect to private vehicle cost has also been estimated in the range between 0 and 0.4 (Litman, 2011). The most significant value of cross elasticity of pkm on rail transport with respect to the air transport cost (in developed countries) was estimated between 0 and 0.2 (Oum, 1990; Börjesson, 2009 and de Bok et. al., 2010)), with the higher estimates referring to a direct competition between air and train (and therefore excluding other public transport modes).

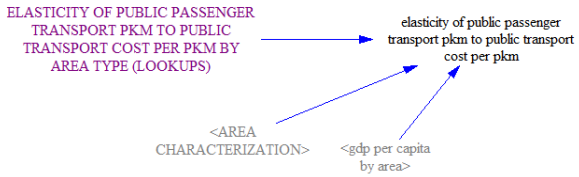
In ForFITS, elasticities are expressed as functions of GDP per capita and of the area type (URBAN, NON-URBAN, NON-SPECIFED):

- Pkm on public transport are assumed to be more sensitive to changes in the cost of public transport when GDP per capita is high (easier shift to alternative options, widely available due to motorization). The elasticity values used by default reflect a more rigid evolution of pkm when average incomes are low because of the lower availability of alternatives. On the other hand, the cross effect due to changes of vehicle travel cost in the competing "driving passenger modes" (personal vehicles and air) is less significant with high incomes (passengers with high incomes tend not to shift to public transport than in low income cases).
- The characterization of different areas, exogenous in the ForFITS Excel file ("Transport system (over time)" tab) allows distinguishing the impact caused by a variation in the cost of driving depending on the area type (URBAN, NON-URBAN, NON-SPECIFIED). By default, pkm on public transport vehicles are assumed to be more rigid in non-urban areas than in urban environments because of the lower availability of alternatives.

Elasticity of public passenger transport pkm to public transport cost

This impact on the target pkm on collective vehicles is calculated as a function of changes on the cost of driving per pkm in the public transport. A negative elasticity results from an increase in the cost of the public transport leading to a reduction in the pkm of collective vehicles. In ForFITS, the default value of the elasticity also depends on the area type which is defined by the user and on the GDP per capita at the current TIME STEP (Figure 6.8).

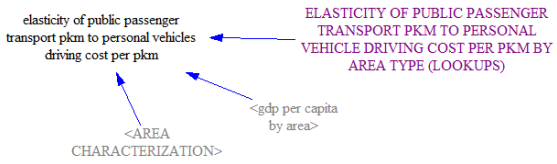
Figure 6.8 Elasticity of public passenger transport pkm to public transport cost: Vensim sketch



Elasticity of public passenger transport pkm to driving cost of personal vehicles

The change in pkm on collective passenger transport is calculated as a function of variations on the personal vehicles driving cost per pkm. A positive elasticity results from an increase in the personal vehicles driving cost leading to an increased use of the public transport. In ForFITS, the default value of the elasticity also depends on the area type which defined by the user and on GDP per capita at the current TIME STEP (Figure 6.9).

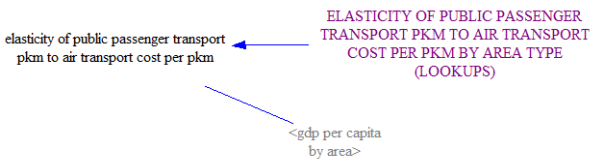
Figure 6.9 Elasticity of public passenger transport pkm to personal vehicle driving cost: Vensim sketch



Elasticity of public passenger transport pkm to air transport cost

The pkm of public transport vehicles is represented as a function of the cross-effect variations in the cost of air passenger transport per pkm. The elasticity is generally positive, since an increase in the cost of air transport leads to an increasing use of public transport. The default value of the elasticity only depends on GDP per capita, since there is no distinction between urban and non-urban areas in this case (Figure 6.10).

Figure 6.10 Elasticity of public passenger transport pkm to air transport cost: Vensim sketch



Outputs

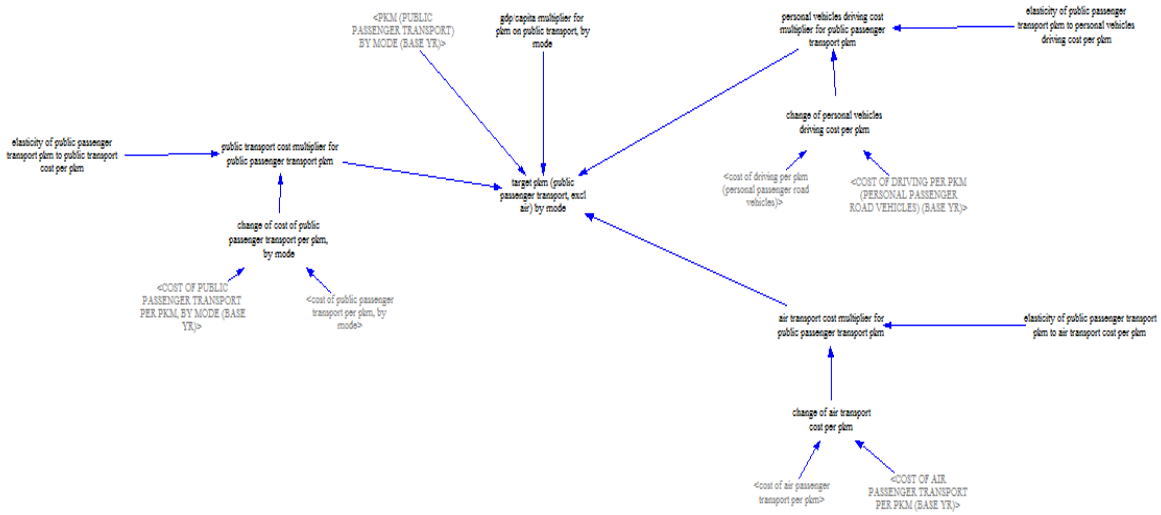
Pkm on collective vehicles as a function of variations in GDP per capita and costs per pkm is represented as (See Figure 6.11):

$$Target\ pkm\ on\ collective\ vehicles\ at\ a\ TIME\ STEP =$$
$$= pkm\ on\ collective\ vehicles\ at\ the\ Base\ Year \times GDP\ multiplier \times\ Cost\ multipliers$$

Each of the three cost multipliers is calculated according to the definition of elasticity:

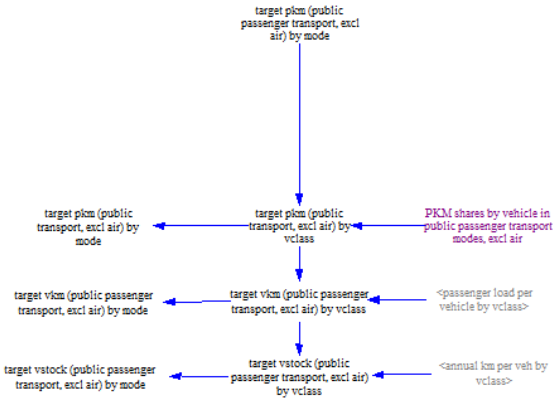
$$Cost\ multiplier = 1 + Elasticity \times Percentage\ change\ on\ the\ cost\ of\ driving$$

Figure 6.11 Calculation of pkm by mode taking into account of the changes of GDP per capita and the cost of driving



The target pkm on collective vehicles by mode is disaggregated across the vehicle classes by the shares (endogenous). The target pkm are lastly converted into target vkm according to the passenger load per vehicle, and subsequently into target vehicle stock dividing by annual travel per vehicle (Figure 6.12). Both average travel and average load are endogenous inputs from the views "travel per vehicle" and "passenger load" (respectively).

Figure 6.12 Pkm, vkm and vehicle stock for public transport, by mode



The target vehicle stock is used to set the new registrations over time of public transport vehicles in the view "vehicles by age". The target vkm and pkm are significant parameters for the calculations on public transport taking place in the "travel per vehicle (passenger)" and "passenger load" views.

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