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The PLANET Model: Methodological Report

PLANET 1.0

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Activities to Support the Federal Policy on Mobility and Transport

Abstract - The PLANET model is a model of the Belgian Federal PLANning Bureau that models the relationship between the Economy and Transport. Its aim is to produce: (i) medium- and long-term projections of transport demand in Belgium, both for passenger and freight transport; (ii) simulations of the effects of transport policy measures; (iii) cost-benefit analyses of transport policy measures. The methodological report describes the main features of the PLANET model.

Jel Classification – R41, R48

Keywords – Freight and passenger transport model, Long-term transport projections, Transport externalities

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Foreword

The work presented in this report was financed by the FPS Mobility and Transport. Its aim is to develop the expertise of the Federal Planning Bureau in the transport area in order to ensure analyses that are consistent both over time and in the approaches that are used. The activities for the support of the federal policy on mobility and transport consist of the development and exploitation of statistical information, of transport projections and of an aid to decision making.

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Executive Summary

The PLANET model is a model of the Belgian Federal PLANning Bureau that models the relationship between the Economy and Transport. The model has been developed in a convention between the FPS Mobility and Transport and the Federal Planning Bureau. The aim of the model is to produce:

- medium- and long-term projections of transport demand in Belgium, both for passenger and freight transport;
- simulations of the effects of transport policy measures;
- cost-benefit analyses of transport policy measures.

In this methodological report we describe the main features of the PLANET model. The report consists of six parts. The following table presents its structure.

Table 1: The structure of the methodological report of PLANET

Chapter	Content
1	Overview of the PLANET modules
2	The Macro module
3	The Transport Generation module
4	The Trip Distribution module
5	The Modal and Time Choice module
6	The Welfare module

The PLANET model is used to develop a business-as-usual scenario for transport in Belgium and to compare this with alternative policy scenarios. The results of the different scenarios are discussed in accompanying reports.

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List of abbreviations

BAU	Business-as-usual
BTM	Bus, tram, metro
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
GDP	Gross domestic product
HDV	Heavy duty vehicle
IWW	Inland waterways
LDV	Light duty vehicle
N_2O	Nitrous oxide
NMVOC	Non-methane volatile organic compounds
NOx	Nitrogen oxides
NST/R	Classification of goods for freight transport (see Annex 7.1)
PCU	Passenger car unit
pkm	Passenger kilometre
PM	Particulate matter
ROW	Rest of the world
SO_2	Sulphur dioxide
tkm	Tonne kilometre
vkm	Vehicle kilometre
VOT	Value of time

1. Overview of the PLANET modules

1.1. Introduction

The PLANET model is a model of the Belgian Federal PLANning Bureau that models the relationship between the Economy and Transport. The model has been developed in a convention between the FPS Mobility and Transport and the Federal Planning Bureau. The aim of the model is to produce:

- medium- and long-term projections of transport demand in Belgium, both for passenger and freight transport;
- simulations of the effects of transport policy measures;
- cost-benefit analyses of transport policy measures.

Given these aims, PLANET should be considered as a model that is complementary to the existing transport models in Belgium. The main strengths lie in the long term horizon of PLANET, the simultaneous modelling of passenger and freight transport and the welfare evaluation of policies. An implication of the strategic nature of PLANET is that it necessarily operates at a more aggregate level than some of the other models.

In the methodological report we describe the main features of the PLANET model. The report consists of six parts. Table 2 presents its structure.

Table 2: The structure of the methodological report

Chapter	Content
1	Overview of the PLANET modules
2	The Macro module
3	The Transport Generation module
4	The Trip Distribution module
5	The Modal and Time Choice module
6	The Welfare module

The Policy module summarises the measures that are taken in each policy scenario. It is discussed together with the description of the business-as-usual and alternative scenarios. The results of these scenarios are discussed in separate reports.

Before describing the different PLANET modules in detail, we first give an overview of the modules and the links between them.

1.2. Overview of the PLANET modules

The current version of PLANET consists of seven interrelated modules[2]: Macro, Transport Generation, Trip Distribution, Modal and Time choice, Vehicle Stock, Welfare and Policy. The relationships between these modules are summarised in Figure 1 and Figure 2.

The first aim of the Macro module is to provide macro-economic projections at the level of the NUTS3 zones for Belgium[3]. This is done by spatially disaggregating results of HERMES[4] and MALTESE, two national projection models. This information is supplemented by demographic and socio-demographic projections. The Macro module is discussed in Chapter 2.

The Policy module summarises the policy instruments that are used in the business-as-usual and alternative scenarios. These consist of transport instruments (such as fuel taxes, ownership taxes or road pricing). Moreover, it defines how additional net tax revenue generated in the transport sector is recycled, or how extra revenue needs in the transport sector are financed.

The transport core of PLANET consists of four modules (see also Figure 2). The Transport Generation module (Chapter 3) derives the total number of commuting and school journeys produced in and attracted to each NUTS3 zone. In addition, it makes a projection of the total number of passenger trips for "other" purposes and of the total tonnes lifted for national and international freight transport. The results of this module are fed into the Trip Distribution module (Chapter 4) which determines the number of trips taking place between each of the zones. In the next step the Modal and Time Choice module (Chapter 5) derives the modes by which the trips are made and the time at which the trips take place (in the case of road transport). These choices depend on the money and time costs of the different options. Travel time for the road modes is determined endogenously, by means of the speed-flow function that gives the relationship between the average speed of the road transport modes and the road traffic levels. The Modal and Time Choice module also provides information on the environmental impacts of transport and on net government revenue obtained from transport. In the current version of PLANET it uses an exogenous evolution of the vehicle stock.

Some of the outcomes of the four transport modules for year t are assumed to influence transport demand in year $t+1$. First of all, the demand for passenger trips for "other" purposes and of tonnes lifted in Belgium by transit freight transport (determined in the Transport Generation module) depends on the average generalised cost of these transport flows in the previous year (determined in the Modal and Time Choice module). Secondly, the generalised transport costs resulting from the Modal and Time Choice module influence trip distribution in the next year. Finally, the composition of the road vehicle stock (currently set exogenously in the Vehicle Stock module) has an impact on the monetary costs of road transport in the next year.

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[2] In the current version of PLANET the vehicle stock is taken from external studies. The assumptions that are used are described in the report on the business-as-usual scenario. The module for the endogenous choice of vehicle types is under construction.

[3] These correspond with the 43 "arrondissementen/arrondissements".

[4] HERMREG, a regional version of HERMES, is under development.

The Welfare module computes the effects of transport policy measures on welfare. It produces a cost-benefit analysis of the transport policy reforms summarised in the Policy module. It takes into account the impact on the consumers, the producers, the government and environmental quality.

Figure 1: The PLANET modules

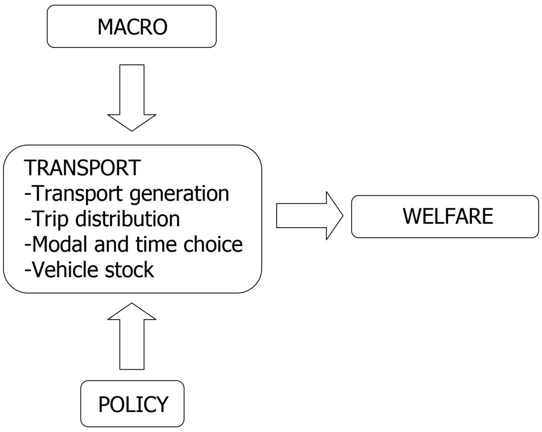
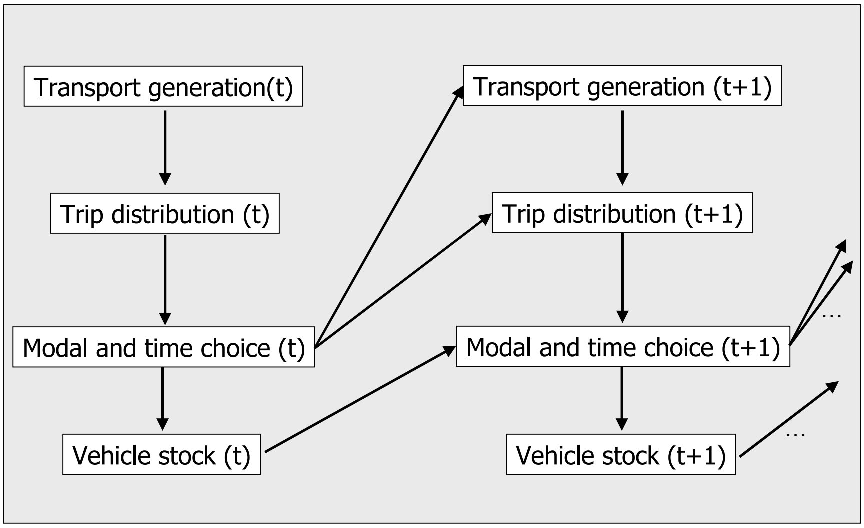


Figure 2: The links between the TRANSPORT modules in PLANET



2. The Macro Module

2.1. Introduction

The aim of the Macro module is to provide macroeconomic, demographic and socio-demographic projections upon which the other modules can build. Section 2.2 describes the methodology for the macroeconomic projections, while the demographic and socio-demographic projections are the subject of Sections 2.3 and 2.4. Section 2.5 summarises the links with the other PLANET modules.

2.2. Macroeconomic projections

The macroeconomic module aims at producing long-term projections (up to 2030) for[5]:

- employment at NUTS3 level;
- production by NST/R chapter[6] at NUTS3 level (at constant prices);
- imports and exports by NST/R product (at constant prices);

Before describing the methodology used to generate these outputs, it is crucial to recall three general principles that have played a role in the choice of the methods and the data sources.

First of all, the aim is to produce *long-term* projections. This means that attention is particularly paid to trend developments (and less to cyclical movements) and to determinants that explain these long-term trends. Furthermore, the macroeconomic module is kept *exogenous*. In this context, exogeneity means that only the impact of economic variables on transport variables is taken into account. There is no feed-back from transport to (macro)economics. Finally, the approach followed is *top-down*, which means that national projections for Belgium serve as a starting point and that the modelling is only aimed at a further disaggregation of these national projections, in particular spatially (to the NUTS3 level) and by product (NST/R classification).

More precisely, maximal coherence with FPB medium and long term projections is aimed at. These projections are generated using the HERMES and the MALTESE model. HERMES is a macrosectoral[7] econometric model with a medium-term horizon. MALTESE is a macroeconomic model used to study typical long-term issues, with special attention to demographic developments. The reference projections used in this report are:

- the medium-term HERMES outlook 2006-2011 published in May 2006, see: FPB/BFP (2006); this projection has been prolonged to 2020 for internal use;
- beyond 2020, the reference projection is the Spring 2006 MALTESE projection, see: HRF/CSF (2006).

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[5] The macroeconomic module also produces projections for the share of imported goods that is re-exported and for the real value per tonne of imports and exports by NST/R product. For the description of these topics, see Chapter 3.

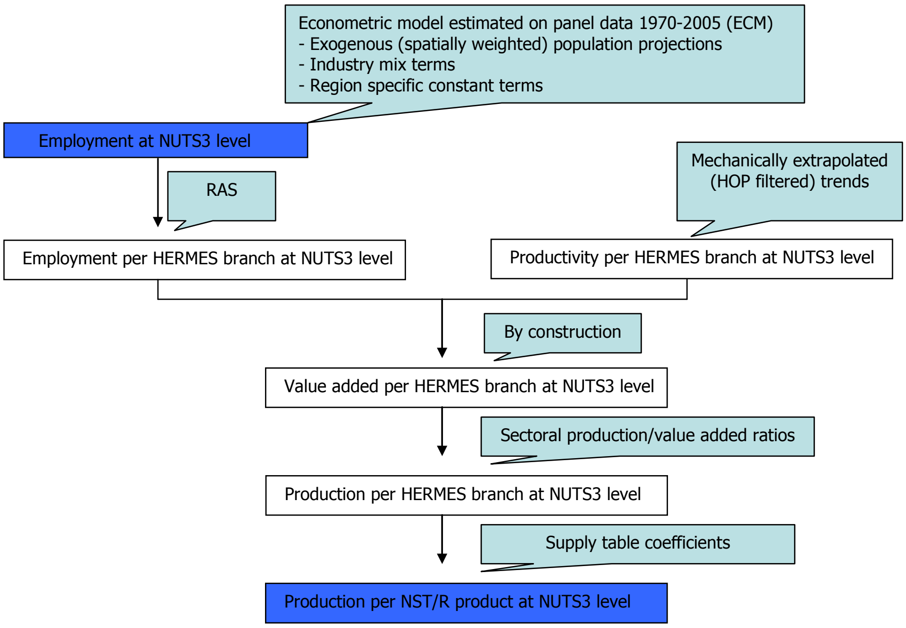
[6] For a definition of the NST/R chapters, see Annex 7.1

[7] In this modelling exercise, we work with the basic HERMES version, distinguishing 12 branches. The more elaborated version of the HERMES model (with a further disaggregation of some services branches) is not useful in this context.

In order to feed this module with the necessary inputs, a lot of work has been done for the construction of the data series. A number of (published and unpublished) data sources have been combined. Where necessary, data have been adjusted to assure full coherence with published National and Regional Accounts.

The disaggregation of national employment and production projections is done jointly. The scheme below summarises the different steps of this disaggregation method. The first step is the spatial disaggregation of employment using an econometric model estimated on panel data. This model allows for the construction of long-term employment dispersion projections based on scenarios for expected structural changes in economic activity and regional demographic projections. Applying a RAS[8] technique on these NUTS3 employment totals and national totals per HERMES branch, employment projections per HERMES branch at NUTS3 level are obtained. Next, projections on value added per HERMES branch at NUTS3 level are calculated based on these employment projections combined with mechanically extrapolated productivity trends. Value added is inflated to production by applying (national) sectoral ratios of production over value added, and, finally, production totals per branch are broken down to NST/R products using splitting coefficients taken from the supply table for Belgium. In the next sections, these steps will be discussed more in detail.

Figure 3: Disaggregation of employment and production projections



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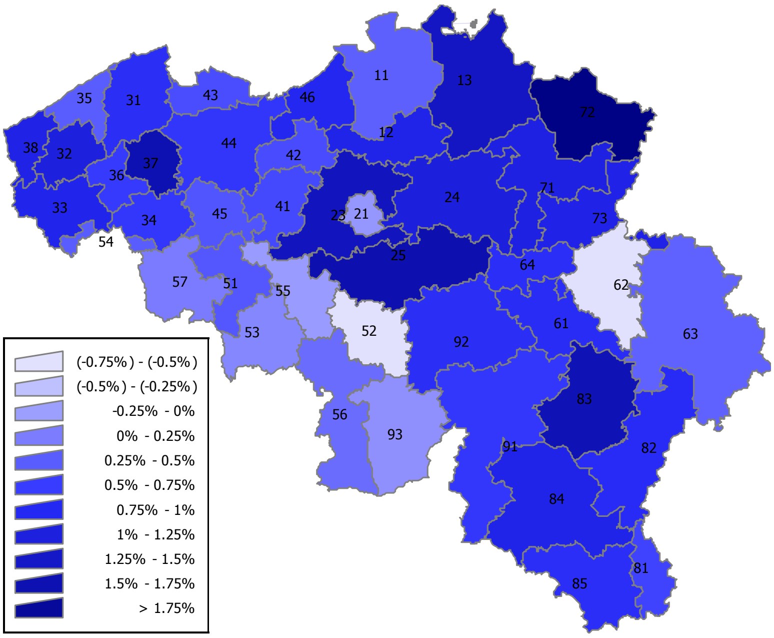
[8] The RAS technique is an iterative procedure to adjust elements of a matrix to sum to known column and row totals.

2.2.1. Regional employment projections

Between 1970 and 2005 (most recent observation), employment increased by 0.4% on average per year in Belgium as a whole. At the NUTS3 level, annual employment growth varied between -0.7% and 2.0% over the same period, with 7 regions experiencing a growth rate above 1%, while 6 regions had to contend with a fall in their employment level. This leads to the conclusion that large regional disparities in employment growth have occurred in Belgium over the past 35 years.

Figure 4: Employment growth at NUTS3 level: 1970-2005 (annual growth rates in %)



Source: NBB, Statistics Belgium, calculations FPB (data on place-of-work basis)

In what follows, we explain how projections of employment at the NUTS3 level up to 2030 have been generated. We follow a top-down approach, in the sense that the development of total Belgian employment (based on FPB medium and long term projections) is taken as given. Using an econometrically estimated model, total domestic employment is then disaggregated at the NUTS3 level.

a. Modelling regional labour market developments for Belgium at NUTS3 level

The regional employment projections are an important input in the Trip Distribution module for passenger transport. Moreover, they provide a basis for the spatial disaggregation of production at the NUTS3 level (see Section 2.2.2).

An important source of inspiration for our modelling attempt is the CPB Regional Labour Market Model for the Netherlands[9]. The CPB model was built to construct long-term quantitative scenarios to assess the planning of residential and business estate areas and large infrastructure projects. So, a first point of resemblance with the CPB model is that our model is also aimed at producing analyses with

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[9] See Vermeulen and van Ommeren (2004) and Verkade and Vermeulen (2005).

a long-term horizon. Also in line with the CPB model, our model takes the scenario for the national labour development as given, and is only meant to generate time paths for its spatial distribution (top-down approach).

In the theoretical literature, a series of possible explanatory factors for uneven regional employment dynamics can be found. Among the most cited are the industry structure of the economic activity, the quantity and quality of labour supply, the extent of innovative activity, geographical location, accessibility and the availability of infrastructure, of other business support services and of natural resources.

In our employment dispersion model, two explanatory variables of this longlist have been identified: regional industry mix and regional labour supply. Other factors are less tangible and/or can less easily be quantified. In so far as non-identified factors are rather constant in time, they can be captured by region-specific constant terms. Attempts to estimate a more complete explanatory model have not been successful.

Regional employment and industry mix: a shift-share analysis

Shift-share analysis is a (purely statistical) technique often used to analyse trends in regional job growth. It allows identification of the parts of regional employment growth disparities that can be attributed to regional differences in industry mix. A region, for example, with a relatively high proportion of employment in fast-growing industries (such as services), is expected to experience a faster employment growth than a region which is specialised in slow-growing or even declining industries, such as agriculture or manufacturing. Differences between this expected (industry-mix-based) outcome and the realised employment growth are then attributed to (at this stage still unidentified) 'region-specific characteristics'.

Figure 5 shows the results of a shift-share analysis based on employment data for Belgium at the NUTS3 level over the period 1995-2005[10]. It compares the observed employment growth between 1995 and 2005 to the employment growth for each region based on its unique industry mix[11]. The plotted regression line shows that, as expected, there is a positive relation between the two outcomes. The scatter plot (summarised in the low value of R-squared), however, indicates that the relationship is rather weak. A favourable industry mix does not guarantee above-average employment growth (this is only true in 6 out of 15 regions), and 9 out of 28 regions perform better than on average in spite of an unfavourable industry mix. All this leads to the conclusion that region-specific factors play a more prominent role in the explanation of regional employment growth differences than the industry mix. This conclusion confirms earlier findings for a large set of countries[12].

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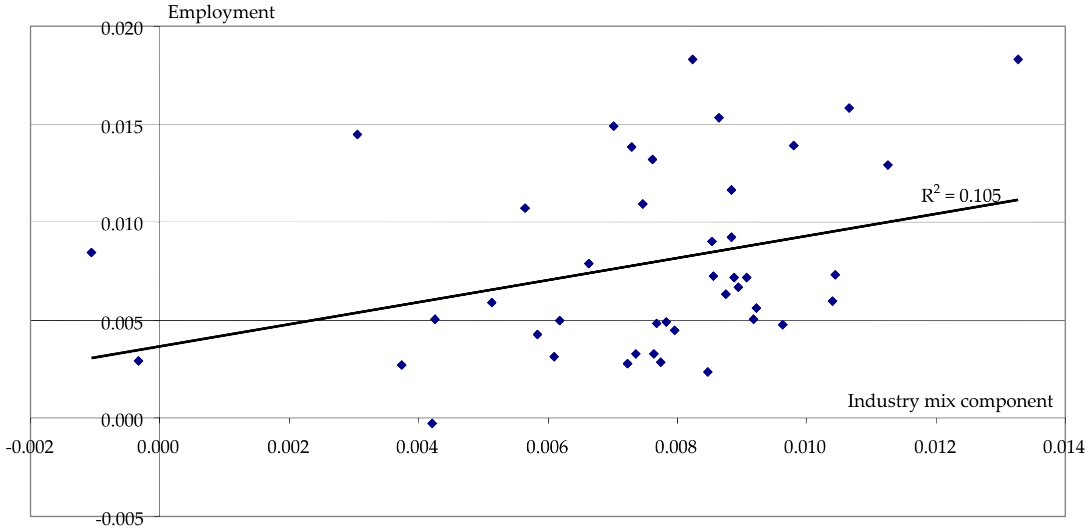
[10] This analysis was made at the most detailed industry level available (113 industries, unpublished data coherent with official Regional accounts 1995-2005). We thank the National Bank of Belgium for providing these data.

[11] The industry mix component has been calculated here as the weighted average of sectoral employment growth figures, with weights depending on each region's initial industry mix. In a dynamic shift-share analysis (as here), the weights change over time.

[12] See OECD (2000), p. 49.

Figure 5: Shift-share analysis 1995-2005: employment and industry mix (annual average growth rates)



Source: NBB, calculations FPB

Regional employment and labour supply

Among the other factors (other than industry mix) explaining uneven employment dynamics, population, and more in particular labour supply, is undoubtedly the most frequently cited. In the real world, labour supply and employment interact simultaneously: labour supply adjusts to shifts in labour demand (job opportunities trigger migration) and *vice versa* (labour supply incites firms to locate near people). Econometric analysis for the Netherlands (made on a comparable spatial disaggregation level) nevertheless reveals that regional population changes have a stronger impact on employment growth than the other way around[13].

Figure 6 shows the relationship at NUTS3 level between employment growth and growth of labour supply (as measured by spatially weighted population of working age[14]) over the period 1970-2005. Over a long time span (for instance the 35 year-period considered in Figure 6), the interaction between employment and population leads to a strong correlation.

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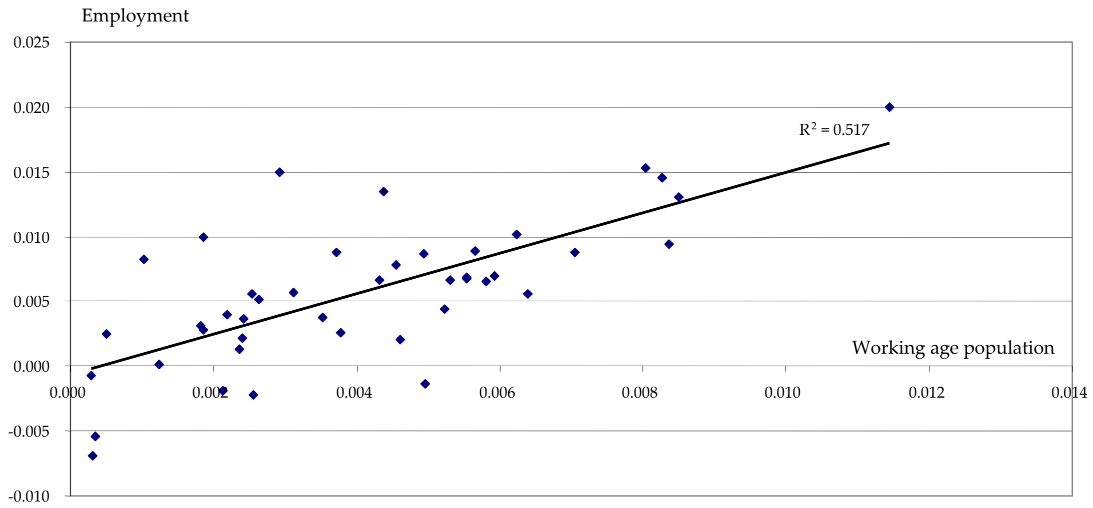
[13] See Vermeulen and van Ommeren (2004).

[14] The population of working age was spatially weighted in order to account for interregional commuting. The weights are based on the origin-destination matrix for commuting taken from the socio-economic survey of 2001.

Figure 6: Employment and working age population: 1970-2005 (annual average growth rates)



Source: NBB, Statistics Belgium, calculations FPB

Unlike the CPB model, in which the equations for net domestic migration and regional employment dispersion have been simultaneously estimated, our model uses exogenous regional population projections. This means that by using our model, we are able to simulate the impact of alternative population scenarios on the regional dispersion of employment. Our model has, however, the disadvantage of not reflecting the simultaneous interaction in the real world of population and employment.

b. Specification of the labour market model

From the preceding discussion, we have learned that the large differences in employment performance across the Belgian NUTS3 zones cannot be explained exclusively by differences in the industry mix. Other 'region specific' characteristics are responsible for generating regional outcomes, which often more than offset the disadvantages or advantages stemming from sectoral structure. Among these other factors, the supply of labour is, especially from a long-term point of view, a very important element.

The model shown below attempts to summarise these findings. Like the CPB model[15], our model is set up as an empirically founded econometric model, estimated on an extensive dataset. The model is estimated on a panel of annual data covering the period 1970-2005 for the 43 Belgian administrative regions[16], corresponding to the Eurostat NUTS3 level. Employment data are on a place-of-work basis. In the officially published Regional Accounts, employment at the NUTS3 level is only available for the period 1995-2005[17]. Population data at NUTS3 level from 1989 onwards are produced and published by the NIS/INS[18]. For the earlier years, employment and population series have been retropo-

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[15] The CPB model is based on data collected at the COROP level (i.e., 40 NUTS3 zones for the Netherlands), covering the 1970-2000 period.

[16] Adding up to domestic employment, exclusive of employment in the extra-regional zone (i.e. the Belgian military in Belgian barracks abroad and the personnel of the Belgian embassies). To domestic employment should be added the personnel of international organisations in Belgium, for which no reliable data exist at the moment.

[17] See INR/ICN (2007).

[18] See http://ecodata.mineco.fgov.be/mdn/bevolking.jsp.

lated by the FPB, based on information from the decennial censuses and historic employment series (from the NIS/INS[19] and the Ministry of Labour).

The estimated model takes the following form:

$$d\ln(EMP_{i,t}) = c_i + d\ln(INDMIX_{i,t}) + a_1 * d\ln(POP_{i,t}) + a_2 * (\ln EMP_{i,t-1} - \ln POP_{i,t-1})$$

Panel data regression model (fixed effects); Estimation period: 1970-2005, 43 NUTS3 zones

Coefficient	Value	(t-stat)
a_1	0.455	(5.0)
a_2	-0.043	(-8.8)

Adjusted R-squared = 0.404

where:

$EMP_{i,t}$ = employment in zone *i* in year *t* ;

$INDMIX_{i,t}$ = industry mix component in zone *i* in year *t* ;

$POP_{i,t}$ = population of working age (spatially weighted, cf. supra) in zone *i* in year *t*.

The model incorporates the industry mix component as explanatory variable.[20] The influence of working age population takes the form of a dynamic specification that distinguishes between short-run and equilibrium adjustment effects (error correction model). The response of employment to working age population is decomposed into an instantaneous reaction (the term expressing the response to population *change*) and an adjustment towards the long-run equilibrium (the term expressing the response to the lagged population *level*). Both estimated coefficients (the short-run coefficient and the coefficient of the long-term adjustment term) have the expected sign and are statistically significant. All other explaining factors are captured by region specific constant terms. In this way, the model controls for unobserved regional heterogeneity (*fixed effects* model)[21]. In the long run, (relative) changes in employment are imposed[22] to be equal to (relative) changes in population of working age.

The above (all in all simple) model explains regional divergences in employment dynamics to some degree (the adjusted R-squared amounts to 40%). It can be used to construct long-term employment dispersion projections based on scenarios for expected structural changes in economic activity (industry mix) and regional demographic projections (working age population).

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[19] For employment data before 1995, see Maeseele (1994).

[20] The coefficient of dln(INDMIX) is not statistically different from one. In the CPB model, no statistically significant relationship between regional dispersion and industry mix could be detected.

[21] Based on the outcome of statistical testing, the fixed effects model is preferable to a model without region specific fixed effects (only one constant term) and to a model with random effects.

[22] ‘ Imposed’ based upon statistical evidence: a coefficient different from one is statistically rejected.

c. Simulation of the model: a two-step procedure

Based on the model described above, exogenous assumptions on the development of the population of working age and given structural changes in economic activity (taken from national projections), a future path for employment at the NUTS3 level was generated (first step simulation).

Next, the first step simulation results were used as distribution keys to disaggregate the exogenous Belgian totals (second step simulation). Total domestic employment is generated by the macrosectoral HERMES model for the years up to 2020 and by the MALTESE model for the years beyond 2020. The MALTESE projection is based on the assumption that the unemployment rate keeps decreasing until 2030. Figure 7 presents the projected development of total employment for Belgium up to 2030.

Figure 7: Projection of total Belgian employment up to 2030

Source: INR/ICN, FPB projections

d. Some results

Table 3 shows the shares of the different NUTS3 zones in total employment as observed in 1970 and 2005 and projected to 2030.

The total share of the five historically (based on the 1970 situation) most important NUTS3 zones (Brussels, Antwerp, Liège, Ghent and Charleroi) fell from 47.4% in 1970 to 40.0% in 2005. Only Ghent succeeded in a small rise of its share between 1970 and 2005. The total share of the five mentioned zones should, according to our projections, fall further to 38.6% in 2030.

The total share of the group of medium-sized NUTS3 zones (11 zones with a share between 2 and 4% in 1970) increased substantially from 30.2% in 1970 to 36.0% in 2005, and it should increase further to 36.7% in 2030. The three most dynamic zones in this group were: Halle-Vilvoorde, Nivelles and Turnhout. Only two zones of this group noted a fall in their share: Verviers and Mons.

Table 3: Regional breakdown of employment at NUTS3 level

	1970	2005	2030
Arr. Brussel/Bruxelles	19.10%	15.61%	15.25%
Arr. Antwerpen	10.87%	10.24%	9.55%
Arr. Liège	7.16%	5.17%	4.95%
Arr. Gent	5.28%	5.62%	5.59%
Arr. Charlerloi	4.94%	3.38%	3.21%
Arr. Halle-Vilvoorde	4.03%	5.63%	5.90%
Arr. Hasselt	3.36%	4.06%	4.02%
Arr. Leuven	3.11%	3.86%	3.93%
Arr. Kortrijk	2.87%	3.04%	3.10%
Arr. Turnhout	2.86%	3.93%	4.15%
Arr. Brugge	2.56%	2.82%	2.66%
Arr. Mechelen	2.53%	2.99%	3.05%
Arr. Verviers	2.37%	2.22%	2.27%
Arr. Namur	2.28%	2.50%	2.53%
Arr. Mons	2.16%	1.84%	1.78%
Arr. Nivelles	2.07%	3.07%	3.30%
Arr. Aalst	1.86%	1.87%	1.82%
Arr. Sint-Niklaas	1.72%	1.97%	1.98%
Arr. Roeselare	1.47%	1.53%	1.54%
Arr. Soignies	1.44%	1.16%	1.16%
Arr. Tournai	1.41%	1.23%	1.20%
Arr. Dendermonde	1.35%	1.34%	1.36%
Arr. Oostende	1.21%	1.15%	1.07%
Arr. Tongeren	1.09%	1.29%	1.33%
Arr. Maaseik	1.04%	1.82%	2.00%
Arr. Oudenaarde	1.01%	0.98%	1.13%
Arr. Thuin	0.88%	0.80%	0.81%
Arr. Ieper	0.83%	0.97%	0.99%
Arr. Mouscron	0.70%	0.66%	0.66%
Arr. Dinant	0.69%	0.73%	0.77%
Arr. Huy	0.64%	0.71%	0.75%
Arr. Tielt	0.64%	0.94%	1.18%
Arr. Eeklo	0.59%	0.59%	0.59%
Arr. Ath	0.52%	0.50%	0.52%
Arr. Arlon	0.47%	0.48%	0.48%
Arr. Philippeville	0.46%	0.38%	0.37%
Arr. Veurne	0.45%	0.54%	0.53%
Arr. Neufchâteau	0.44%	0.52%	0.55%
Arr. Waremme	0.36%	0.40%	0.43%
Arr. Marche-en-Famenne	0.33%	0.48%	0.53%
Arr. Diksmuide	0.31%	0.38%	0.40%
Arr. Bastogne	0.28%	0.32%	0.34%
Arr. Virton	0.26%	0.29%	0.29%
Total domestic employment (excl. extra-regional)	100%	100%	100%

Source: NIS/INS, INR/ICN, FPB projections

The total share of the group of the small NUTS3 zones (27 zones with a share below 2% in 1970) increased from 22.4% in 1970 to 24.0% in 2005, and it is expected to increase further to 24.8% in 2030. The most striking performances in the group of small zones were observed in Maaseik, Tielt, Tongeren, Sint-Niklaas and Marche-en-Famenne. Zones of this group that noted a clear fall of their share are Soignies and Tournai.

This leads to the general conclusion that employment has become less spatially concentrated in Belgium over the past 35 years, with medium-sized and small regions experiencing a faster employment growth than the five (historically) largest regions. According to our projections, this trend should continue during the coming decades, albeit at a somewhat slower pace.

2.2.2. Regional production projections by product

This section describes the methodology used to generate production projections by product (NST/R) at NUTS3 level up to 2030. As no historic figures for these series are available, past series have first been constructed taking into account available information from Regional Accounts and national Supply and Use Tables. For the projection of these series, maximal coherence with employment projections at NUTS3 level and FPB medium and long term output projections is aimed at.

a. Data sources

Production figures per goods category (NST/R) are an input in the Transport Generation module for freight transport. Moreover, production figures at the NUTS3 level per goods category are required as input to the Trip Distribution module. These figures, however, are not available for Belgium. In this section we explain how these figures have been constructed for the past and how they are projected to the future.

The methodology makes use of the following sources of information. A number of the sources mentioned below relate to unpublished data (because of their detailed disaggregation level), but they are fully coherent with published National and Regional Accounts.

- Gross value added at current prices, at NUTS3 level and disaggregated into 114 branches (unpublished NBB data, coherent with INR/ICN (2006)), aggregated to 12 HERMES branches (1995-2004).
- Employment figures at NUTS3 level and disaggregated into 114 branches (unpublished NBB data), aggregated to 12 HERMES branches (1995-2005).
- The detailed supply table for Belgium of the year 2000, 324 products x 121 branches (unpublished NBB data), aggregated to 10 NST/R products and 12 HERMES branches.
- Gross value added projections per HERMES branch (up to 2020).
- Employment projections for Belgium per HERMES branch up to 2020.
- Employment projections at NUTS3 level up to 2030 (see previous section).

b. Three-step method

Based on the data mentioned above, a three-step method has been developed to compute production figures at the NUTS3 level per goods category for the period 2000-2030. The first step consists of the generation of value added per HERMES branch at NUTS3 level, based on projected employment and labour productivity. The second step is the translation of value added to production, both at NUTS3 level per HERMES branch. In the final step, production figures are broken down to NST/R products.

Step 1: Value added per HERMES branch at NUTS3 level

Employment per HERMES branch at NUTS3 level

Employment figures at NUTS3 level per HERMES branch are available for the period 1995-2005. In Section 2.2.1, we described how employment projections at NUTS3 level for the period 2006-2030 were constructed. The purpose here is to disaggregate these employment projections by HERMES branch.

The method used is the so-called RAS technique, making use of:

- the 2005 (most recently observed) employment structure (NUTS3 level per HERMES branch);
- row totals: employment projections per NUTS3 zone for the period 2006-2030 (see Section 2.2.1);
- column totals: total employment projections per HERMES branch for the period 2006-2030.

Concerning the total employment projections per HERMES branch, two sub-periods can be distinguished:

- up to 2020 these sectoral employment projections are taken from the May 2006 HERMES projection;
- beyond 2020, the development of total employment is taken from the 2006 MALTESE projection[23] and the sectoral composition of total employment has been mechanically extrapolated based on trends up to 2020.

From the above we can conclude that the employment projections at NUTS3 level per HERMES branch concurrently take into account the expected shifts in spatial dispersion of employment (as explained in Section 2.2.1) and the shifts in sectoral shares given at the Belgian level.

Labour productivity per HERMES branch at NUTS3 level

This section explains how labour productivity per HERMES branch is calculated and extrapolated at NUTS3 level.

Based on unpublished Regional Accounts data, the ratio of gross value added (at current prices) to employment can be calculated at NUTS3 level and per HERMES branch for the period 1995-2004. Expressing these ratios relative to the corresponding Belgian total ratio per HERMES branch, an indicator of the relative productivity development per HERMES branch is obtained[24]. Figure 8 illustrates this for the branch of manufactured consumer goods (HERMES branch C) in Tielt. Almost one third of total employment in Tielt works in that branch. Figure 8 shows that the Tielt productivity level in that branch was 5% higher in 1995 than on average in Belgium in the same branch, and that this difference increased to 20% in 2004.

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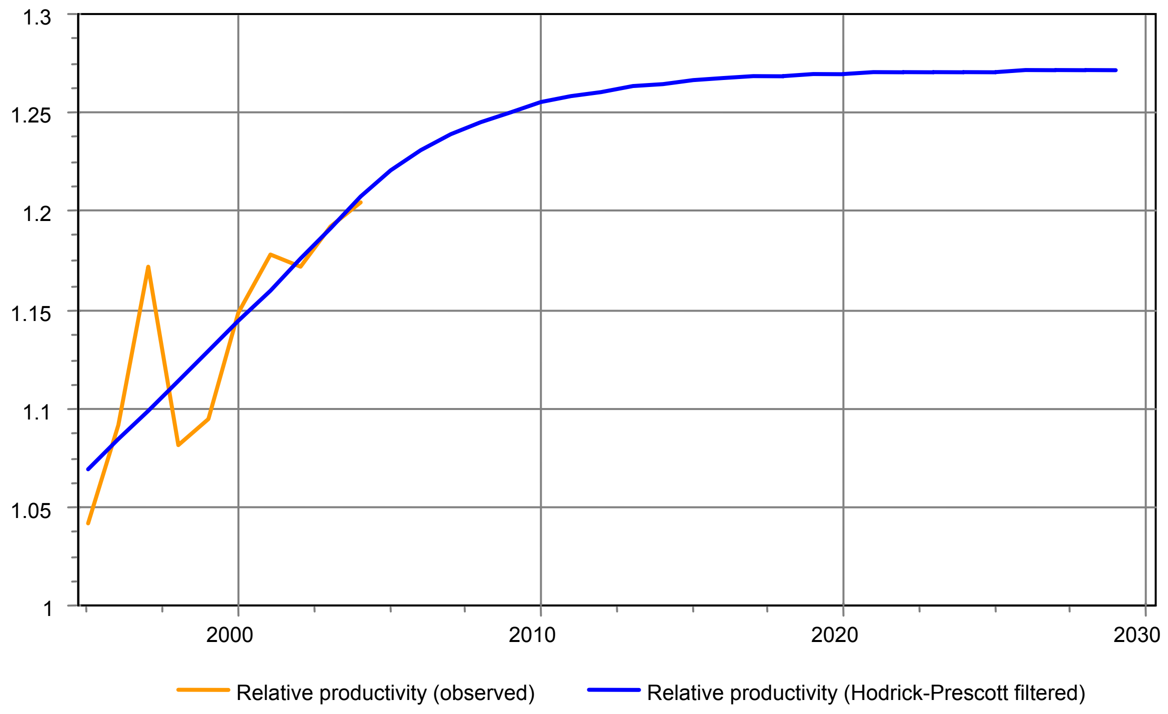
[23] The MALTESE model only generates total employment projections for Belgium, but no sectoral breakdown.

[24] Assuming that price developments per branch in all NUTS3 zones are identical. For lack of useful data on regional differences in value added deflator developments, this assumption is also made in the Regional Accounts. The calculated regional productivity differences can be due to differences in the more detailed sectoral breakdown or to 'real' productivity differences (in identical detailed sectors).

Figure 8: Relative productivity: manufactured consumer goods in the Tielt example



Source: INR/ICN, FPB projections

To correct for year-to-year volatility, the past (1995-2004) trends are first calculated by applying the Hodrick-Prescott filter. Taking the 2004 trend levels as starting point, the relative productivity developments are extrapolated on the basis of a purely mechanical method. The projections can be considered as rather cautious, as past trends are assumed to level off by the end of the projection period. In the case of the consumer goods industry in Tielt, this would lead to a productivity difference of about 27% in 2030.

Valued added per HERMES branch at NUTS3 level

Multiplying the projected employment and (relative) productivity levels per HERMES branch at NUTS3 level, one obtains a first estimate of value added per HERMES branch at the NUTS3 level. These first estimates are then used as distribution keys to split projected (HERMES-MALTESE) value added for Belgium. In that way, the final value added projections per HERMES branch at NUTS3 level are fully compatible with national projections.

This leads to the conclusion that the spatial breakdown of projected value added takes account of:

- differences in the sectoral specialisation of NUTS3 zones;
- differences in employment developments of NUTS3 zones;
- differences in productivity developments of NUTS3 zones.

Step 2: Production per HERMES branch at NUTS3 level

Value added per HERMES branch at the NUTS3 level is next inflated to production by applying sectoral ratios of production over value added[25]. The ratios applied here are taken from the HERMES projection up to 2020 and mechanically extrapolated afterwards. The underlying assumption is that the sectoral Belgian coefficients that transform value added into production hold in all NUTS3 zones.

Step 3: Production at NUTS3 level by NST/R product

In this final step, total production per HERMES branch at the NUTS3 level is assigned to product categories, using splitting coefficients taken from the supply table[26] of the year 2000 for Belgium. Again, the underlying assumption is that the sectoral Belgian coefficients that break down sectoral production to different product categories hold in all NUTS3 zones. Moreover, these coefficients are assumed to remain constant over time.

c. Some results

The described method finally results in disaggregated production projections up to 2030 (10 NST/R product categories x 12 HERMES branches x 43 zones).

The sum of these production data corresponds to the production of goods[27]. Figure 9 shows the projected development (up to 2030) of the production of goods and compares it to the projected total output (goods and services). Production of goods is expected to grow at a slower pace than total production (by 1.5% on average per year compared to 2.2%). Accordingly, the share of goods in total production should decrease over the projection period (from 34.4% in 2000 to about 28% in 2030). This downward movement is the continuation of a historic trend: the share of goods production in total production was still above 40% at the beginning of the eighties[28].

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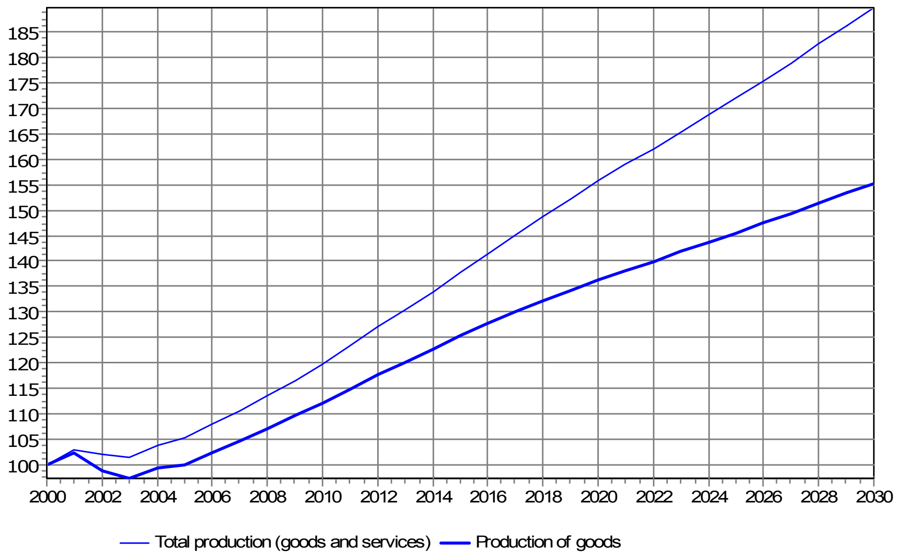
[25] Production equals value added (so-called 'primary inputs') plus intermediate inputs. The ratios thus represent the importance of intermediate inputs in total production.

[26] The detailed supply table (324 products and 113 branches) was first aggregated to 10 NST/R chapters and 12 HERMES branches. The aggregation rules (for branches and products) can be found in Annex 7.1 and 7.3.

[27] Goods are here defined as CPA 01-37. Services (CPA 40-99) are excluded in the NST/R-classification, as they are not physically transported.

[28] Retropolation based on internal FPB data.

Figure 9: Development of production (at constant prices, 2000=100)



Source: INR/ICN, FPB projections

The reason for the falling share of goods in total production is shown in Table 4. While the manufacturing industry (HERMES sectors Q, K and C) represents only 30% of total production, its share in the production of goods is 83%. More than 95% of the production of goods is situated in manufacturing industry, agriculture and the energy sector. These branches that are overrepresented in the production of goods are expected to grow more slowly than total production.

Table 4: Production by industry

HERMES branch	2000		2030//2000
	[1]	[2]	[3]
A Agriculture	1.4	4.0	0.4
E Energy	4.7	8.0	1.4
Q Intermediate goods	11.2	31.0	1.4
K Equipment goods	7.9	22.1	1.5
C Consumer goods	11.0	30.3	1.4
B Construction	6.7	0.6	2.4
HA Trade and catering	14.3	2.9	2.9
Z Transport and communication	8.8	0.4	2.8
CR Credit and insurance	4.9	0.0	1.8
SA Health care	4.4	0.0	2.5
OS Other market services	17.8	0.7	2.5
N Non-market services	7.0	0.0	2.0
Total	100.0	100.0	2.2

[1] Share in total production (goods and services) (%)

[2] Share in production of goods (%)

[3] Annual growth rate (at constant prices, in %)

Source: INR/ICN, FPB projections

Table 5 shows the shares of the different product types in total goods production[29]. Projected variations of the shares over time are all in all limited, partly because of the assumption of constant product structures of sectoral production.

Table 5: Shares of product types in total production of goods (2000-2030) (at constant prices)

NST/R chapter	2000	2030
0 Agricultural products and live animals	4.3	3.4
1 Foodstuff and animal fodder	14.0	13.9
2 Solid mineral fuels	0.0	0.0
3 Petrol products	5.9	5.7
4 Ores and metal waste	0.0	0.0
5 Metal products	9.2	9.2
6 Crude and manufactured minerals; building materials	2.8	2.9
7 Fertilizers	0.0	0.0
8 Chemicals	17.2	17.4
9 Machinery, transport equipment, manufactured articles	46.6	47.3
Total	100.0	100.0

Source: INR/ICN, FPB projections

2.2.3. Projections of imports and exports by product

The objective of this sub-module is to make projections of imports and exports (at constant prices) at product level (NST/R classification). Maximal coherence with FPB medium and long term projections is aimed at. The observed product structure of imports and exports for the year 2000 serves as a starting point; data series for the period 2001-2030 are simulated.

The sources and methods used for the projection of imports and exports by product are described below. In a first point the construction of the base data for the year 2000 will be explained. The second section describes the simulation method. The third section summarises the global results.

a. Base data for the year 2000

Total imports and exports are taken from the Belgian Supply and Use table (SUT) for the year 2000[30]. These totals take only goods[31] into account and correspond to the national concept. Import and export data according to the national concept are, compared to data according to the community concept, better linked to domestic economic activity. Data according to the community concept closely follow the physical movements of goods and include for instance acquisitions (imports) followed by sales (re-exports) done by non-resident companies in Belgium. Based on the Belgian foreign trade statistics, total exports and imports according to the national concept represent more than 80% of total foreign trade according to the community concept. In the PLANET model, distinction is made between foreign trade according to the national concept (described in this section) and transit trade.

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[29] Note that the share of NST/R7 in Table 5 equals zero. This is because the correspondence table between SUT pro-ducts and NST/R chapters (see Annex 7.3) does not allow to isolate NST/R7. Fertilizers are de facto included in NST/R8. Therefore, in PLANET we always consider the aggregate of NST/R7 and NST/R8 (denoted by NST/R7_8).

[30] Source: internal data coherent with INR/ICN (2005).

[31] More precisely CPA 01 to 37, industrial services excluded (P.61/P.71).

The breakdown of total imports and exports (SUT totals) by NST/R chapter is based on data taken from the so-called 'Yearbook of Foreign Trade Statistics' (National Bank of Belgium). This yearbook contains the most detailed figures on Belgium's foreign trade: imports and exports of more than 10,000 different products, by partner country, expressed in value and quantity. In this database, imports and exports by type of product are represented according to the structure of the Combined Nomenclature at 8-digit level. These CN-8 data have, for the purpose of the PLANET model, been converted to import and export data by product according to the NST/R classification. Unfortunately, the data series at this level of detail are only available according to the community concept. We therefore assume that the product composition of foreign trade according to the national concept is identical to the composition of imports and exports according to the community concept.

Based on these sources, the breakdown of the total value of Belgian imports and exports by type of product in 2000 is given in Table 6. The share of machinery, transport equipments, manufactured articles etc. (NST/R9) and chemicals (NST/R8) in total imports and exports of goods lies between 70 and 75%. Petrol products (NST/R3) are the third most important product group at the import side, but (logically) less important (only number six) at the export side.

Table 6: Breakdown of Belgian imports and exports by type of product (NST/R) in 2000 (%)

NST/R chapter	Imports	Exports
0 Agricultural products and live animals	3.2	3.2
1 Foodstuff and animal fodder	6.7	7.2
2 Solid mineral fuels	0.3	0.1
3 Petrol products	7.0	4.3
4 Ores and metal waste	1.3	0.5
5 Metal products	4.9	6.7
6 Crude and manufactured minerals; building materials	5.0	4.6
7 Fertilizers	0.3	0.5
8 Chemicals	16.9	20.4
9 Machinery, transport equipment, manufactured articles…	54.3	52.6
Total	100.0	100.0

Source: INR/ICN, FPB calculations

b. Simulation up to 2030

Total imports and exports of goods have been extrapolated based on GDP projections taken from FPB medium and long-term projections (HERMES up to 2020 and MALTESE for the years beyond 2020) and the trend elasticity[32] of imports and exports of goods relative to GDP.

The breakdown of imports and exports per NST/R chapter for the years up to 2020 is based on HERMES projections. The HERMES model generates import and export projections for six broad categories of goods: agricultural products, solid fuels, petrol products, intermediate goods, equipment goods and consumer goods. The simulation is of course not done at the level of the 10,000 CN-8 products, but for some 200 SUT products[33]. These SUT products are linked to the best matching

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[32] Elasticity calculated using the Hodrick-Prescott filter over the period 1980-2005.

[33] The product classification in the SUT (Supply and Use table) of 2000 is a regrouping of the CPA (Classification of Products by Activity), distinguishing some 200 goods and 125 services.

HERMES product, taking into account the elasticity[34] between the corresponding NST/R chapter and the related HERMES product(s). The projected import and export data by SUT product are next converted to NST/R chapters. These results per NST/R chapter are used as distribution keys to disaggregate total exports and imports. The correspondence between SUT, NST/R and HERMES products and the corresponding elasticities used in this method are given in Annex 7.3 and 7.4. The product composition projected beyond 2020 is based on the continuation of trends up to 2020. Moreover, the projection of imports of NST/R2 takes account of the expected increase of solid fuels in electricity production after 2020, that should stem from the competitive advantage of solid fuels compared to natural gas.

Finally, it should be mentioned that for product NST/R6 a special treatment has been followed. The reason is that, from a transport point of view, this product category is extremely heterogeneous: it contains both precious stones (with a very high value per tonne) and building-materials (with a very low value per tonne). Due to this heterogeneity, the NST/R6 average value per tonne is very sensitive to shifts within this product category. For that reason, this product category was split into two and for each part a projection of the future values was made.

c. Some results

This section summarises the global results of the methodology described above, in terms of projected total imports and exports of goods and in terms of projected product composition of foreign trade.

Figure 10 shows the past and projected profile of foreign trade of goods. To get a clearer view on the long-run underlying trend, the series have been smoothed using the Hodrick-Prescott filter. Foreign trade[35] is projected to grow by 3.6% per year during the period 2005-2030, which is somewhat lower than during the last 25 years (4.2% during the period 1980-2005). This should bring the value of imports and exports (at constant prices) in 2030 at a level of almost two and a half times the level of the year 2005. In the medium term, foreign trade growth should remain close to current trend growth rate of 4%, but it should gradually fall back to about 3% by the end of the projection period. This pattern is consistent with the expected demographic developments and the weakening in the growth of global economic activity.

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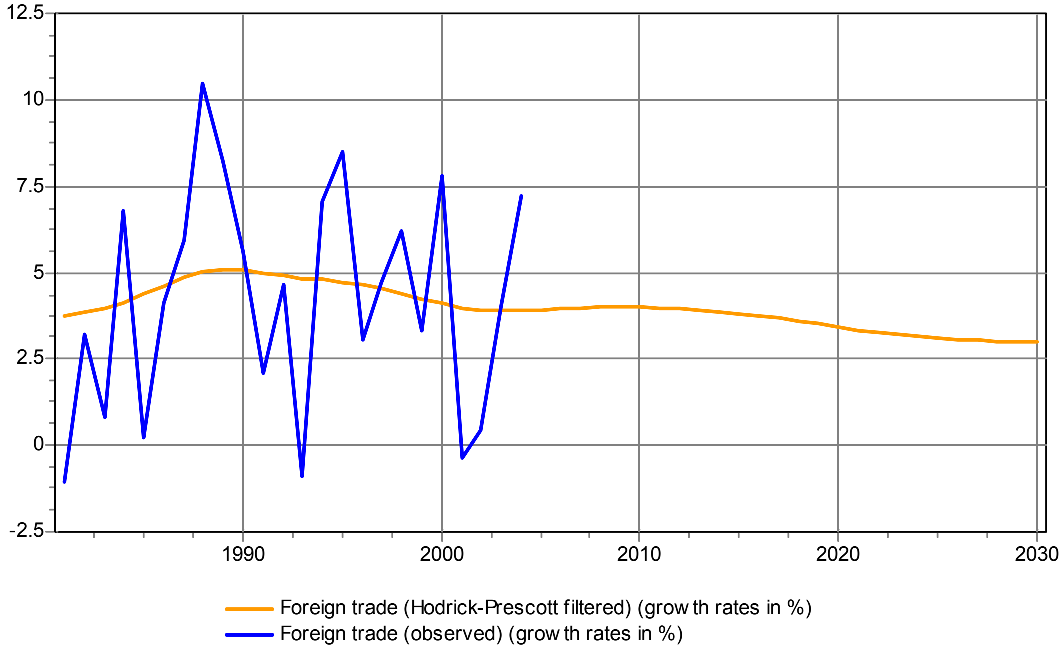
[34] The elasticities have been calculated separately for imports and exports using data for the period 1995-2004. These elasticities allow NST/R products to grow faster or slower than the related HERMES product or (weighted) combination of HERMES products.

[35] Measured here as the sum of total exports and imports of goods at constant prices.

Figure 10: Development of foreign trade of goods (at constant prices, growth rates in %)



Source: INR/ICN, FPB projections

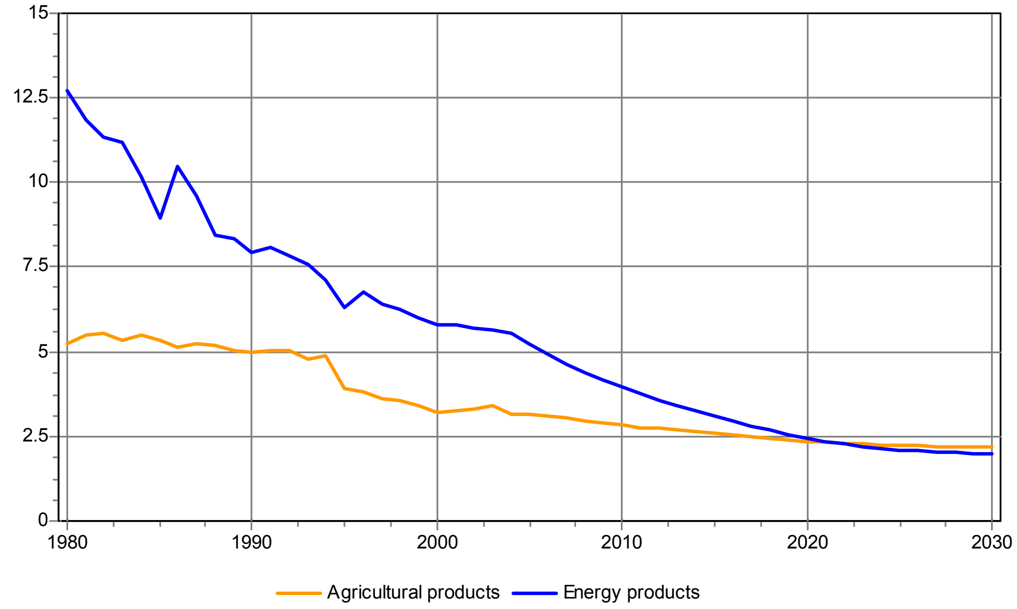
Table 7 shows the projected product composition of imports and exports of goods. The most striking shift in the product composition of foreign trade is the growing importance of chemicals (NST/R8) at the expense of agricultural (NST/R0) and energy products (NST/R2 and 3). The decreasing shares of agricultural and energy products are the continuation of observed historic trends (see Figure 11).

Table 7: Projected breakdown of Belgian imports and exports by type of product (NST/R) (%)

NST/R chapter	Imports		Exports	
	2000	2030	2000	2030
0 Agricultural products and live animals	3.2	2.1	3.2	2.2
1 Foodstuff and animal fodder	6.7	5.9	7.2	6.2
2 Solid mineral fuels	0.3	0.1	0.1	0.0
3 Petrol products	7.0	2.4	4.3	1.5
4 Ores and metal waste	1.3	1.3	0.5	0.5
5 Metal products	4.9	4.3	6.7	5.0
6 Crude and manufactured minerals; building material	5.0	5.1	4.6	4.4
7 Fertilizers	0.3	0.2	0.5	0.2
8 Chemicals	16.9	23.0	20.4	27.6
9 Machinery, transport equipment, manufactured articles…	54.3	55.6	52.6	52.4
Total	100.0	100.0	100.0	100.0

Source: INR/ICN, FPB projections

Figure 11: Decreasing shares of agricultural and energy products (in % of total foreign trade)



Source: INR/ICN, FPB projections

2.3. Demographic data and projections

An important input in PLANET is the future population and its composition in terms of age, sex and household type in each of the NUTS3 zones. In addition, we need information on the socio-economic status of the population. This last aspect will be discussed in Section 2.4. Here we focus on the demographic projections.

We proceed in two steps. First, we consider the demographic projections at the individual level, as they were constructed by the FPB. These provide us with the population per NUTS3 zone according to age and sex. Section 2.3.1 describes some of the data from this study. Next, we use a study by GéDAP (Desmet et al., 2007) which derives the share of different household types using the FPB study as a basis. This is discussed in Section 2.3.2.

2.3.1. Demographic projections at the individual level

The demographic projections at the individual level start from the observations on 1 January 2002. However, the assumptions on fertility, mortality and internal and external migrations are the same as in the last official projections elaborated jointly by the NIS/INS, the FPB and the scientific community, which took 1 January 2000 as the starting point (NIS/INS et al., 2001).

Table 8: Assumptions for the demographic projections at the individual level (Belgium, 2000-2050)

	1950 (obs)	2000	2010	2030	2050
Total fertility rate	2.34	1.61	1.66	1.70	1.75
Life expectancy at birth – men	62.04(*)	75.06	77.23	80.96	83.90
Life expectancy at birth – women	67.26(*)	81.53	83.35	86.43	88.87
International migration balance	-10 362	18 445	16 893	17 358	17 320

(*) Mortality table 1946 - 1949, NIS/INS

Source: NIS/INS et al. (2001)

The total fertility rate (average number of children per woman) would increase slightly from a value of 1.61 in 2000 to 1.75 in 2050, with women recovering at a later age part of the births that they postponed before.

The life expectancy at birth would continue to increase, at a slower pace than in the last few decades. In winning 8.8 and 7.3 years respectively in the period 2000-2050, newly born men could hope to live on average 83.9 years with the mortality conditions of 2050, and women 88.9 years. Comparing this with the corresponding values for 1950, the table shows a considerable increase in life expectancy. In one century, from 1950 to 2050, men and women would gain approximately 22 years in average life expectancy.

The internal migrations included in the projections concern the changes in residence between NUTS3 zones, which amount to 20% of the annual changes in residence taking place within Belgium. Half of the changes in residence take place within the same municipality and 30% between municipalities in the same NUTS3 zone. Belgium is administratively subdivided into 43 NUTS3 zones. In order to project the population in the German-speaking Region, it is isolated from the NUTS3 zone of Verviers, creating a fictive 44th NUTS3 zone.

The internal migrations are determined by the average probability of emigration from each NUTS3 zone to each of the other NUTS3 zones. The schedule by age and the direction and importance of the migrations are obtained by analysing the recent behaviour of the NUTS3 zones that are similar in terms of the degree of urbanisation (urban, peri-urban or rural). This leads to eight possible interrelations. The location of the NUTS3 zones and, more specifically, the average distance that separates them are also taken into account.

For international migrations the projections assume a persisting pressure to immigration coming from southern countries and Eastern Europe. The migratory balance would remain at a high and almost constant level throughout the period, fluctuating between 18 445 in 2000 and 17 300 in 2050 (0.16% of the population in 2050).

Table 9 presents the share of the NUTS3 zones in the total Belgian population in 2001 and 2030, and the projected cumulated population growth rates per NUTS3 zone for the period 2001-2030. The total population in Belgium is projected to grow by 567000 individuals (or 5.5%) between 2001 and 2030. The increase in the population is mainly due to net external immigration. In most years there also is a net natural increase in the Belgian population (i.e., the number of births more than compensates for the number of deaths). However, this increase becomes smaller and smaller and eventually becomes a net natural reduction.

The population increase is larger in Brussels than in Wallonia and Flanders. The underlying factors are different in the three regions. In Brussels there is a net internal emigration to the rest of the country, but this is compensated by a natural increase in the population and by net external immigration. Without net external immigration the population would fall. In Flanders there is a natural increase in the population in the first years. However, after 2006 the number of births is smaller than the number of deaths. Net internal and external immigration is predicted. Without the latter the Flemish population would fall by 2030. In Wallonia all three factors lead to an increase in the population. The highest contribution is made by net internal immigration.

Table 9 also presents the cumulated growth rates for the NUTS3 zones, which range from -5.2 (Ieper) to 17.5% (Waremme).

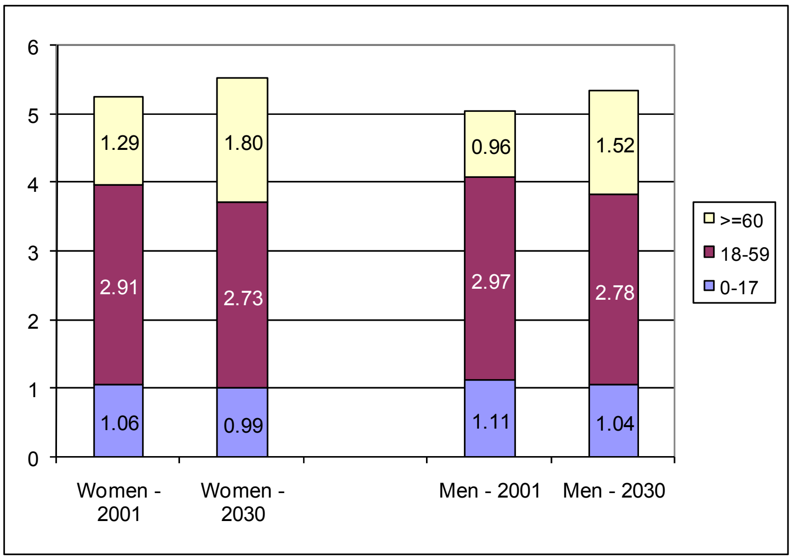
Figure 12 summarises the expected evolution of the Belgian population in terms of age and sex between 2001 and 2030. Both the number of men and women increases, by respectively 4.9% and 6.1%. Three age classes are considered: 0-17, 18-59 and ≥60. In this period there will be an important increase in the share of people older than 59 years, for both sexes. The share of the two other age classes decreases.

Table 9: Population per NUTS3 zone and region (share in 2001 and 2030; cumulated growth rates 2001-2030)

	Share in 2001 (%)	Share in 2030 (%)	Growth rate 2001-2030 (%)		Share in 2001 (%)	Share in 2030 (%)	Growth rate 2001-2030 (%)
NUTS3 ZONES							
Antwerpen	9.07	8.67	0.80	Charlerloi	4.08	4.03	4.10
Mechelen	2.98	3.00	5.88	Mons	2.41	2.47	7.82
Turnhout	3.98	4.05	7.46	Mouscron	0.68	0.62	-2.93
Brussel/Bruxelles	9.46	9.77	8.97	Soignies	1.70	1.79	11.13
Halle-Vilvoorde	5.46	5.49	5.94	Thuin	1.42	1.44	6.86
Leuven	4.46	4.66	10.44	Tournai	1.37	1.33	2.67
Nivelles	3.44	3.75	14.93	Huy	0.98	1.06	14.19
Brugge	2.64	2.44	-2.56	Liège	5.68	5.73	6.39
Diksmuide	0.47	0.43	-2.99	Verviers	2.60	2.71	10.03
Ieper	1.01	0.91	-5.23	Waremme	0.67	0.75	17.46
Kortrijk	2.70	2.46	-4.04	Hasselt	3.75	3.72	4.81
Oostende	1.39	1.33	0.69	Maaseik	2.15	2.23	9.28
Roeselare	1.37	1.28	-1.44	Tongeren	1.85	1.85	5.32
Tielt	0.85	0.79	-2.03	Arlon	0.51	0.54	11.16
Veurne	0.55	0.55	4.18	Bastogne	0.40	0.43	11.82
Aalst	2.56	2.46	1.72	Marche-en-Famenne	0.50	0.55	17.05
Dendermonde	1.81	1.78	3.31	Neufchâteau	0.54	0.56	8.40
Eeklo	0.77	0.72	-1.25	Virton	0.47	0.49	7.91
Gent	4.84	4.68	2.04	Dinant	0.98	1.03	11.03
Oudenaarde	1.11	1.08	2.12	Namur	2.77	2.88	9.78
Sint-Niklaas	2.18	2.15	3.72	Philippeville	0.60	0.60	5.11
Ath	0.77	0.79	7.77				
REGIONS							
Brussels Capital	9.5	9.8	9.0				
Flanders	58.0	56.7	3.2				
Wallonia	32.5	33.5	8.6				
Total			5.5				

Source: NIS/INS et al. (2001)

Figure 12: Composition of the Belgian population according to age class (millions)(2001 and 2030)



Source: NIS/INS et al. (2001)

2.3.2. Demographic projections at the household level

On the basis of the individual demographic projections that are presented in Section 2.3.1, GéDAP has developed demographic projections per type of household to which the individuals belong (Desmet et al., 2007). PLANET considers five household types: single, single with children, couple, couple with children and "other" households. The last category includes individuals living in a collective household (such as, e.g., prisons, social institutions, retirement homes) and individuals living in a complex household, i.e. a household with more than one family nucleus[36]. Because of this latter assumption the household classification differs from that of the NIS/INS.

Table 10 summarises the definition of the household types.

Table 10: The definition of the household categories

Type of individual	Household type to which the individual belongs
Single	Single
Head of one-parent family Child in one-parent family	Single + child(ren)
Married, living with spouse without children Cohabiting, living with a partner without children	Couple
Married, living with spouse and with one or more children Cohabiting, living with a partner and with one or more children Child in family with married parents Child in family with cohabiting parents	Couple + child(ren)
Individual living in a collective household Individual or head of household living in a household with more than one family nucleus	Other

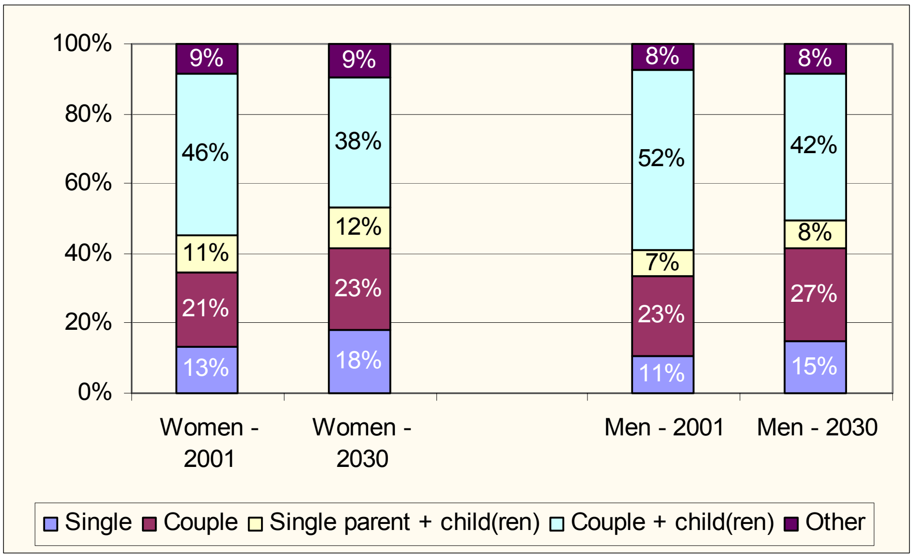
---

[36] A family nucleus can be a small family unit (couples with or without children, single parent with children) or a single person.

In addition, GéDAP has made a careful analysis of the population data for 2002, which is the base year for the GéDAP projections. It was found that the official household type does not always correspond with the actual one. A correction has been made for this by GéDAP. This implies that a similar correction needs to be made to the data of the SES2001. More particularly, we start from the corrected database for 2002 that was constructed by GéDAP and assume that the share of household types per NUTS3 zone, age and sex is the same in 2001 and 2002.

To give a flavour of the results, Figure 13 summarises the expected evolution in individuals according to the household type between 2001 and 2030 at the national level. An important shift in the share of the household types is expected. The share of individuals living in a household of a couple with child(ren) falls, while the share of individuals belonging to all other household types increases. The projected increase is the highest for individuals living as a single.

Figure 13: Composition of the Belgian population by household type (2001 and 2030)



Source: own calculations on the basis of GéDAP

2.4. Socio-economic status

The transport behaviour of individuals depends not only on their age, sex and household type, but also on their socio-economic status. We make a distinction between students, people with a job and others – that are termed "inactive". Transport demand differs between these types of people. The future projections of transport demand therefore require information on the number of people per NUTS3 zone, age, sex, household type and socio-economic position. The demographic projections provide information on the first four dimensions. Here we discuss how the projections about the socio-economic status are constructed. We consider three age classes: 0-17, 18-59 and ≥60. The methodology used for the first age class differs from that used for the two other groups. Section 2.4.1 discusses the methodology for the age group 0-17, while Sections 2.4.2 and 2.4.3 cover the other age groups. Section 2.4.4 presents the resulting projections per socio-economic class at the national level. These are broken down at the NUTS3 level in Section 2.4.5.

2.4.1. The socio-economic status of the age class 0-17: base year and projections

For the base year the SES2001 provides information about the socio-economic position of the population. However, the share of inactive people in the age class 0-17 seems to be unrealistically high. Therefore, we have decided not to use the data of the SES2001 on the socio-economic status and to make the following assumptions instead for this age group:

- the number of working people is set equal to zero;
- the number of inactive people is set equal to the number of people between 0 and 2.5 years old;
- the number of students is calculated as a rest category.

Table 11 presents the resulting data for Belgium as a whole and compares them with the data of the SES2001. For the share of the other dimensions (sex, household type and NUTS3 zone) we continue to use the data of the SES2001.

Table 11: The socio-economic status of the age group 0-17 in the base year

Socio-economic status	Number of people	
	SES2001	SES2001 corrected
Student	1436511	1876262
Job	9332	0
Inactive	716100	285926
Non-response	245	
Total	2162188	2162188

Source: SES2001 and FPB

The same assumptions are made for the period 2005 to 2030.

2.4.2. The socio-economic status of age groups 18-59 and ≥60 in the base year

For the age groups 18-59 and ≥60 we use the figures of MALTESE (HRF/CSF, 2007). However, some adjustments are made to these data since the age classes in MALTESE do not correspond completely with those used in PLANET. MALTESE provides figures for the age classes 15-19, 20-59 and ≥60. In order to use these data we split the age class 15-19 into two categories: 15-17 and 18-19. It is assumed that all people in the age class 15-17 are students and that none of them have a job. Table 12 gives the original employment and student rates at the national level of MALTESE, together with the rates that were derived for the age classes used in PLANET.

Table 12: National employment and student rates (2001)(%)

		Employment rate	Student rate
MALTESE – original data			
Men	15-19	16.3	79.6
	20-59	78.7	3.6
	≥60	10.7	0.0
Women	15-19	12.6	83.6
	50-59	62.2	3.9
	≥60	3.1	0.0
Rates based on MALTESE, using age classes of PLANET			
Men	18-59	77.1	5.6
	≥60	10.7	0.0
Women	18-59	60.9	6.2
	≥60	3.1	0.0

Source: MALTESE and own calculations

2.4.3. Projections of socio-economic status of age classes 18-59 and ≥60

For the projections of the socio-economic status for the age classes 18-59 and ≥60 we start from the demographic projections of NIS/INS et al. (2001) and GéDAP. We assume that the number of students in the age class ≥60 equals zero.

To derive the student and employment rates for the future we start from the MALTESE model which provides long-term projections of these rates per age class and sex. For the medium term these projections are consistent with HERMES. However, the projections are available only at the national level. Moreover, the age classes do not completely correspond with the ones used in PLANET. To transform the rates into rates for the appropriate age classes we make the same assumptions as those used above for the base year.

Table 13: Evolution of the employment rates between 2001 and 2030

		2001	2005	2010	2015	2020	2025	2030
MALTESE - original data								
Men	15-19	16.3	13.1	13.7	14.4	14.9	15.2	15.5
	20-59	78.7	76.4	78.0	78.7	79.9	80.5	81.2
	≥60	10.7	11.2	12.1	13.2	13.6	13.2	12.3
Women	15-19	12.6	11.0	11.8	12.6	13.2	13.5	13.7
	20-59	62.2	63.4	67.5	70.5	73.1	74.6	75.6
	≥60	3.1	3.7	4.9	5.7	6.7	7.0	6.7
Transformation of MALTESE rates using age classes of PLANET								
Men	18-59	77.1	74.7	76.0	76.9	77.9	78.7	79.4
	≥60	10.7	11.1	12.1	13.2	13.5	13.2	12.3
Women	18-59	60.9	61.9	65.8	68.8	71.3	72.9	73.8
	≥60	3.1	3.7	4.9	5.7	6.7	7.0	6.7

Source: MALTESE and own calculations

Table 14: Evolution of the student rates between 2001 and 2030

		2001	2005	2010	2015	2020	2025	2030
MALTESE – original data								
Men	15-19	79.6	81.5	81.5	81.5	81.6	81.6	81.5
	20-59	3.6	3.5	3.7	3.7	3.7	3.7	3.7
	≥60	0	0	0	0	0	0	0
Women	15-19	83.6	84.7	84.5	84.6	84.6	84.6	84.6
	20-59	3.9	3.8	3.9	4.0	4.0	4.0	4.0
	≥60	0	0	0	0	0	0	0
Transformation of MALTESE rates using age classes of PLANET								
Men	18-59	5.6	5.7	5.9	5.9	6.0	5.8	5.8
	≥60	0	0	0	0	0	0	0
Women	18-59	6.2	6.3	6.5	6.4	6.6	6.4	6.4
	≥60	0	0	0	0	0	0	0

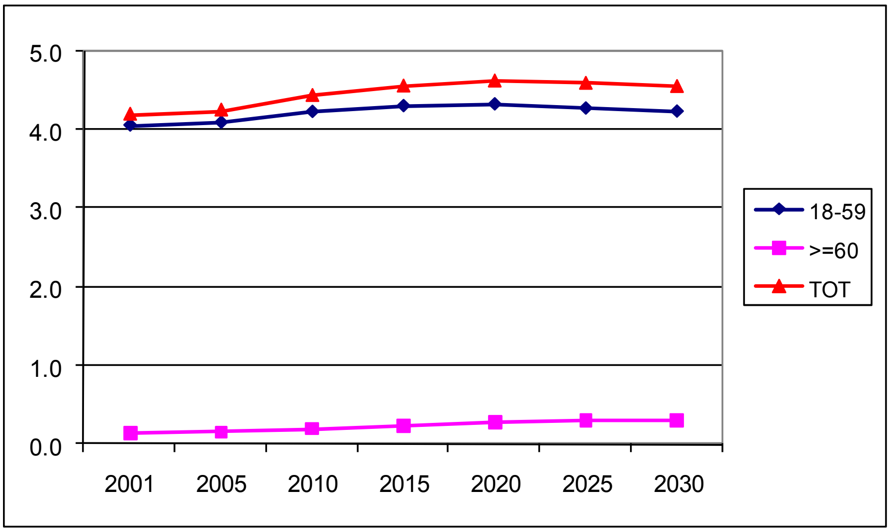
Source: MALTESE and own calculations

2.4.4. Projections of the socio-economic status – national level

Figure 14 to Figure 16 give the resulting projections for the number of employed persons, students and inactive persons.

The number of employed persons is projected to increase until 2020 when 10% more people are employed than in 2001. After 2020 the working population falls to a level in 2030 that is 8% higher than in 2001.

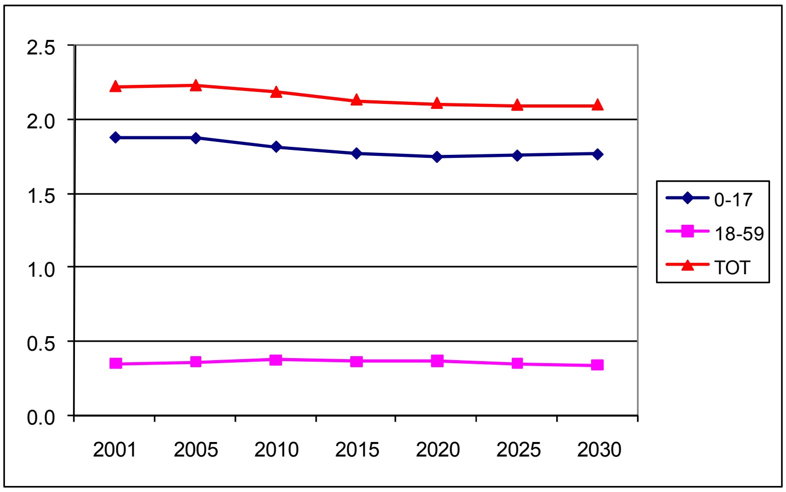
Figure 14: Projected number of employed persons per age class – 2001-2030 (millions)



Source: FPB

Figure 15 presents the results for the number of students. In the age class 0-17 the number of students is projected to fall by some 6% in the period 2001-2030. This evolution is determined completely by the changes in the total population in this age class and by the share of children younger than 2.5 years. The student population in the age class 18-59 first increases and then falls. In 2030 it is approximately 2.5% lower than in 2001. Its share in the student population fluctuates between 15.6% and 17.3%.

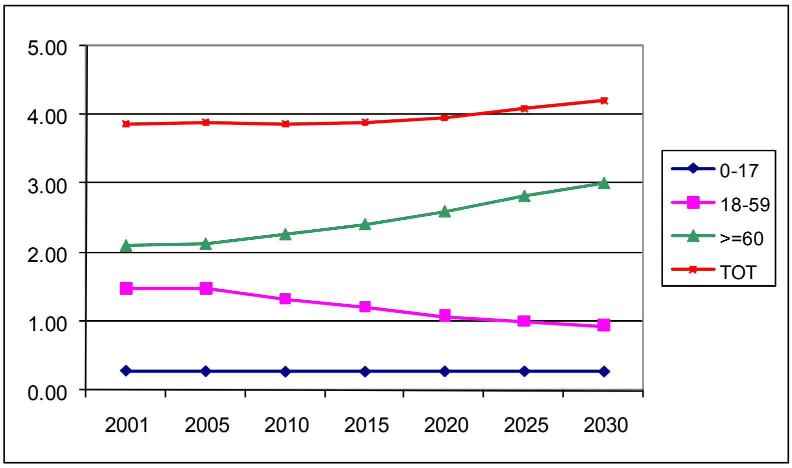
Figure 15: Projected number of students per age class – 2001-2030 (millions)



Source: FPB

The projected changes are the largest for the inactive population, as can be seen in Figure 16. The number of inactive people increases by 9% between 2001 and 2030. This is entirely due to the evolution in the age class ≥60, for which an increase by 43% is projected. In the two other age classes the number of inactive persons is expected either to remain constant (age class 0-17) or to fall (age class 18-59).

Figure 16: Projected number of inactive persons per age class – 2001-2030 (millions)



Source: FPB

2.4.5. Projections of socio-economic status – NUTS3 level

The projections of the national employment and student rates need to be broken down at the level of the NUTS3 zones. To our knowledge no model exists for Belgium that can guide us with this. Therefore, we make a number of simplifying assumptions. It should be noted that the methodology to determine the place of residence of the working population and students is quite simple and mechanical. It would be better to determine the location of households endogenously in the model, based on the characteristics of the zones in terms of economic activity, transport characteristics etc. However, this would imply a substantial modelling effort, which is not feasible given the time constraints of our exercise.

We illustrate the methodology for the case of the employment rates. A similar methodology is used for the student rates. The number of inactive people in each NUTS3 zone is calculated as a rest category.

To obtain the future employment rates per NUTS3 zone, we start from the fact that

$$E_t^{a,s} = \sum_i \sum_h e_{i,t}^{a,s,h} p_{i,t}^{a,s,h}$$

In this expression $E_t^{a,s}$ is the national employment rate for people of age *a* and sex *s* in year *t*. $e_{i,t}^{a,s,h}$ is the employment rate of people of age *a*, sex *s* and household type *h* in zone *i*. $p_{i,t}^{a,s,h}$ is the population share of zone *i* for each population group.

For the base year we have information on all components of this expression. However, for the period 2005-2030 we only have projections for the national employment rate per age and sex and the share of the different zones for each population group. The employment rates of each population group in each of the NUTS3 zones need to be derived.

To do so we make the simplifying assumption that the proportional change in the employment rates is the same for each zone and for each household category. In that case

$$E_{t+1}^{a,s} = \sum_i \sum_h K_{t+1}^{a,s} e_{i,t}^{a,s,h} p_{i,t+1}^{a,s,h}$$

From this we can derive the value of the proportionality factor *K*:

$$K_{t+1}^{a,s} = \frac{E_{t+1}^{a,s}}{\sum_i \sum_h e_{i,t}^{a,s,h} p_{i,t+1}^{a,s,h}}$$

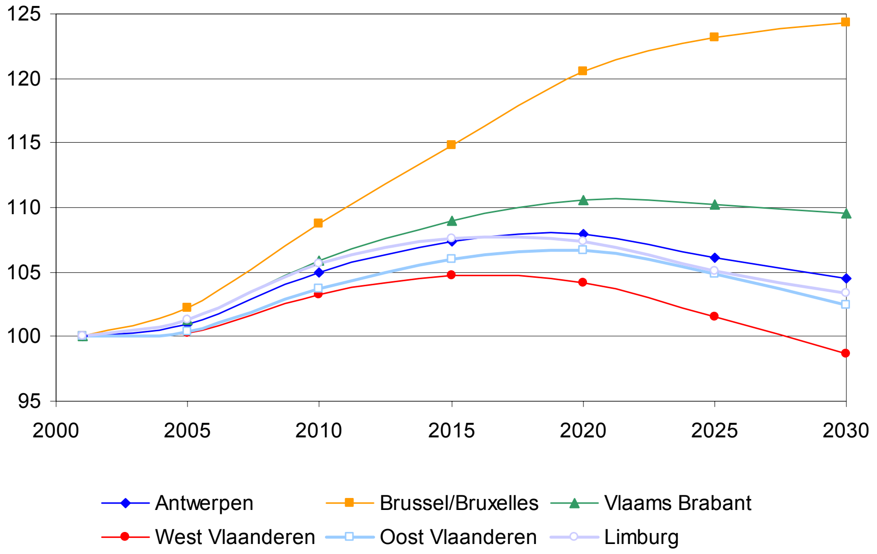
and we can compute

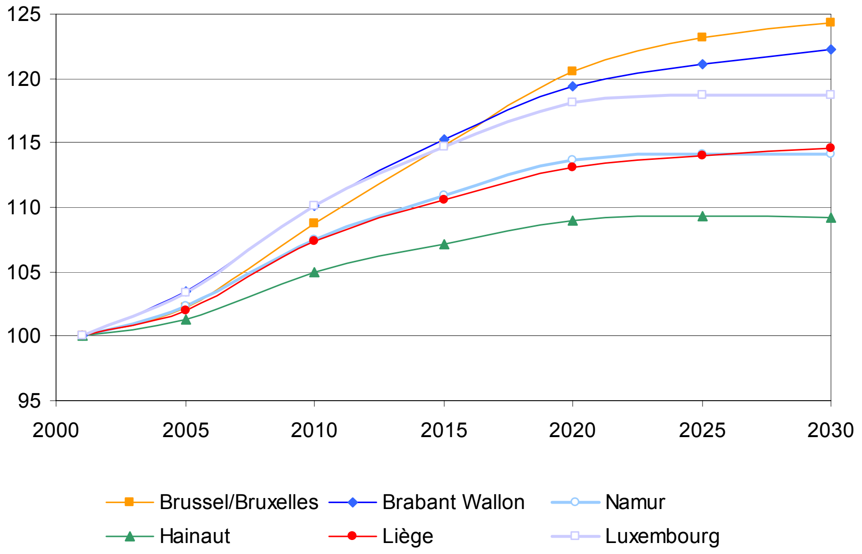
$$e_{i,t+1}^{a,s,h} = K_{t+1}^{a,s}\, e_{i,t}^{a,s,h}$$

It should be noted that with this method the zonal employment rates basically depend on the composition of the population (by sex and age) and on the national employment rates per sex and age.

Figure 17 presents the projected evolution in the number of employed persons per NUTS2 zone relative to 2001. Results are also available at the level of the NUTS3 zones.

Figure 17: Projected evolution in the number of employed persons per NUTS2 zone – 2001-2030 (2001=100)





Source: FPB

In some NUTS3 zones the relative changes are quite high. However, it should be borne in mind that for some of these zones the initial share in total employment is low. To put things in perspective, Table 15 presents the share of each NUTS3 zone and region in the total working population in 2001 and 2030. In most cases the changes in the shares are relatively small and generally less than or equal to 0.3 percentage points. An exception to this are Brussels and Nivelles which increase their share by respectively 1.2 and 0.5 percentage points.

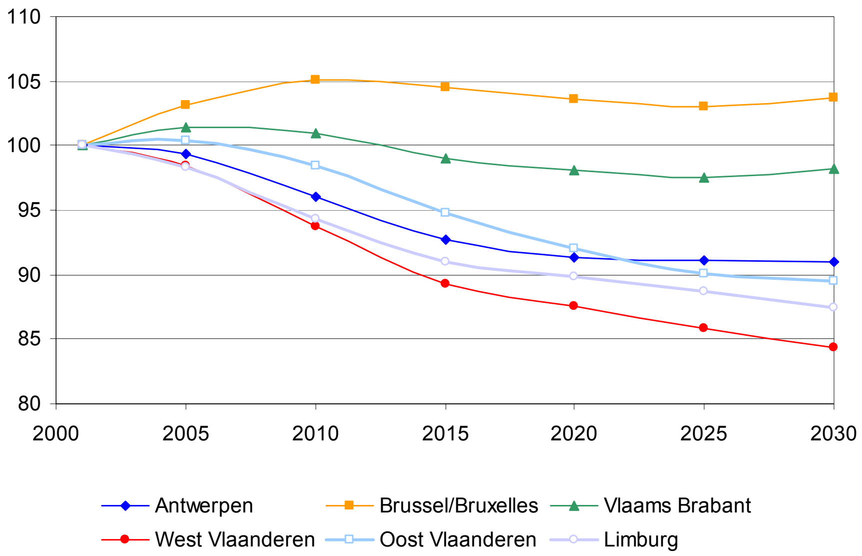
Finally, the different parts of Figure 18 present the projected evolution in the number of students per NUTS2 zone relative to 2001. The evolution is determined mainly by the change in the population in the age class 0-17. Results are also available at the level of the NUTS3 zones.

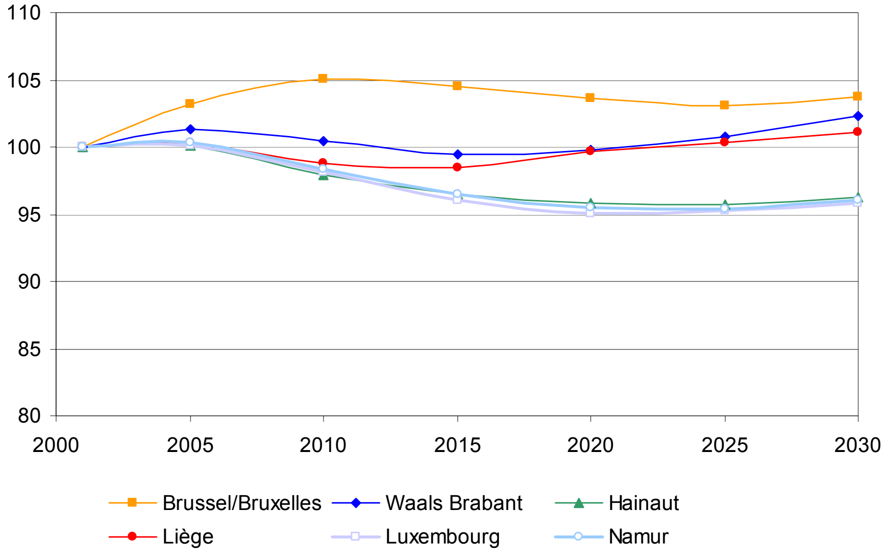
Table 15: Working people per NUTS3 zone and region (share in total working population in 2001 and 2030)(%)

	Share in 2001	Share in 2030		Share in 2001	Share in 2030
NUTS3 zones					
Antwerpen	9.1	8.8	Charlerloi	3.3	3.3
Mechelen	3.2	3.1	Mons	1.9	2.0
Turnhout	4.4	4.1	Mouscron	0.6	0.6
Brussel/Bruxelles	8.2	9.4	Soignies	1.5	1.6
Halle-Vilvoorde	6.0	6.1	Thuin	1.2	1.3
Leuven	5.0	5.1	Tournai	1.3	1.3
Nivelles	3.5	4.0	Huy	0.9	1.0
Brugge	2.8	2.5	Liège	4.9	5.1
Diksmuide	0.5	0.4	Verviers	2.6	2.7
Ieper	1.1	1.0	Waremme	0.7	0.8
Kortrijk	2.9	2.6	Hasselt	3.9	3.6
Oostende	1.4	1.3	Maaseik	2.3	2.2
Roeselare	1.5	1.4	Tongeren	1.9	1.8
Tielt	1.0	0.9	Arlon	0.5	0.6
Veurne	0.5	0.5	Bastogne	0.4	0.4
Aalst	2.9	2.6	Marche-en-Famenne	0.5	0.5
Dendermonde	2.0	1.9	Neufchâteau	0.5	0.6
Eeklo	0.8	0.8	Virton	0.5	0.5
Gent	5.4	5.1	Dinant	0.9	1.0
Oudenaarde	1.2	1.2	Namur	2.7	2.8
Sint-Niklaas	2.4	2.3	Philippeville	0.5	0.5
Ath	0.7	0.8			
REGIONS					
Brussels Capital	8.2	9.4			
Flanders	62.1	59.4			
Wallonia	29.7	31.2			

Source: FPB

Figure 18: Projected evolution in the number of students per NUTS2 zone – 2001-2030 (2001=100)





Source: FPB

Table 16 presents the share of each NUTS3 zone and region in the total student population in 2001 and 2030. In most cases the changes in the shares are relatively small.

Table 16: Students per NUTS3 zone and region (share in total student population in 2001 and 2030)(%)

	Share in 2001	Share in 2030		Share in 2001	Share in 2030
NUTS3 zones					
Antwerpen	8.9	8.7	Charleroi	4.0	4.0
Mechelen	2.8	2.7	Mons	2.5	2.7
Turnhout	3.7	3.5	Mouscron	0.7	0.6
Brussel/Bruxelles	9.9	10.9	Soignies	1.7	1.8
Halle-Vilvoorde	5.4	5.5	Thuin	1.4	1.4
Leuven	4.9	5.2	Tournai	1.3	1.3
Nivelles	4.1	4.4	Huy	1.0	1.1
Brugge	2.4	2.1	Liège	5.9	6.3
Diksmuide	0.4	0.4	Verviers	2.7	2.8
Ieper	1.0	0.8	Waremme	0.7	0.8
Kortrijk	2.6	2.3	Hasselt	3.6	3.4
Oostende	1.2	1.2	Maaseik	2.1	1.9
Roeselare	1.3	1.1	Tongeren	1.7	1.6
Tielt	0.8	0.7	Arlon	0.5	0.5
Veurne	0.5	0.5	Bastogne	0.4	0.4
Aalst	2.2	2.1	Marche-en-Famenne	0.5	0.5
Dendermonde	1.7	1.6	Neufchâteau	0.6	0.6
Eeklo	0.7	0.6	Virton	0.5	0.5
Gent	5.4	5.1	Dinant	1.0	1.0
Oudenaarde	1.0	0.9	Namur	3.1	3.2
Sint-Niklaas	2.1	1.9	Philippeville	0.6	0.6
Ath	0.7	0.8			
REGIONS					
Brussels Capital	9.9	10.9			
Flanders	56.1	53.7			
Wallonia	34.0	35.4			

Source: FPB

2.5. Links with the other PLANET modules

The links of the Macro module with the other PLANET modules are summarised in the following table:

Table 17 : Output of the Macro module of period *t* to the other PLANET modules

	Output to:	Year
Real value of domestic production, import and export (per goods type) Share of imports that is re-exported Real value per tonne (national, Belgium to ROW, ROW to Belgium) per goods type Population per NUTS3 zone + composition (according to age, sex, household type and socio-economic status) Working population per NUTS3 zone Real GDP per capita	Transport generation	*t*
Characteristics of the origin and destination zones in Belgium for domestic freight trips The number of jobs and the supply of education per zone	Trip distribution	*t*
Generalised income per capita	Vehicle stock	*t*

3. The Transport Generation Module

3.1. Introduction

The Transport Generation module uses the results of the Macro module to determine for the period 2000-2030:

- the number of tonnes lifted for national, international and transit freight transport, with a distinction according to NST/R category;
- the passenger trips or journeys "produced" by each Belgian NUTS3 zone, with a distinction between three trip purposes: commuting, school and other purposes;
- the total number of commuting and school journeys attracted to each Belgian NUTS3 zone.

The structure of this report is as follows. Section 3.2 first describes the methodology and data used for freight transport generation. Section 3.3 then turns to passenger transport generation. The results of the Transport Generation module are described in a separate report on the business-as-usual scenario.

3.2. Freight transport generation

Based on the macroeconomic projections of the Macro module (cf. Chapter 2) the freight Transport Generation module of PLANET determines freight transport generation in future years, i.e. the tonnes lifted for national and international transport. Section 3.2.1 first discusses the general methodology for projecting tonnes lifted. Next, Section 3.2.2 turns to the data inputs for this exercise.

3.2.1. Methodology

a. National tonnes lifted

National tonnes lifted are assumed to be related to the value of domestic production and the value of imports. In addition, we take into account the observation from the supply-use tables that a share of the imported goods is re-exported immediately. This share is unlikely to be transported nationally and is therefore subtracted from the value of imports.

The number of national tonnes (indicated by subscript nat) lifted of good *i* in year *t* is determined as follows:

$$TON_{nat,i,t} = \frac{\left[VAL_{dom,i,t} + VAL_{import,i,t}\left(1 - SHARE_{\text{re-export,i,t}}\right)\right]}{\left(\dfrac{VAL_{dom,i,2000} + VAL_{import,i,2000}\left(1 - SHARE_{\text{re-export,i,2000}}\right)}{TON_{nat,i,2000}}\right) r_{nat,i,t}}$$

$$= \frac{\left(VAL_{dom,i,t} + VAL_{import,i,t}\left(1 - SHARE_{\text{re-export,i,t}}\right)\right)}{VALTON_{nat,i,2000}\ r_{nat,i,t}}$$

$TON_{nat,i,t}$ refers to national tonnes lifted of good *i* in year *t*. $VAL_{dom,i,t}$ and $VAL_{import,i,t}$ give the value of domestic production and imports of good *i* in year *t* in constant prices of 2000. $SHARE_{re\text{-}export,i,t}$ is the share of imported goods that is re-exported immediately. $VALTON_{nat,i,2000}$ is the value per tonne for national transport in 2000. $r_{nat,i,t}$ is the ratio of the value per tonne of national transport of good *i* in year *t* to the value per tonne in 2000.

b. International tonnes lifted

The tonnes lifted from Belgium to the rest of the world (subscript *BEROW*) consist of two components: exported tonnes and transit tonnes from Belgium to the rest of the world (ROW) with transhipment. The evolution of exported tonnes depends on the evolution of Belgian exports. Transit transport with transhipment ($TRANSIT_{BEROW,i,t}$) can be expected to be determined by other factors: the magnitude of trade between countries in the ROW ($trade_t$) and the transport costs on routes which pass through Belgium relative to the transport costs on routes that do not pass through Belgium ($transport\ prices_t$). Therefore, ideally, the number of tonnes transported in year *t* from Belgium to the ROW should be determined as follows:

$$TON_{BEROW,i,t} = \frac{VAL_{export,i,t}}{\left(\frac{VAL_{export,i,2000}}{TON_{export,i,2000}}\right) r_{export,i,t}} + TRANSIT_{BEROW,i,t}\left(\text{trade}_t, \text{transport prices}_t\right)$$

$VAL_{export,i,t}$ give the value of exports of good *i* in year *t* in constant prices of 2000. $TON_{export,i,t}$ refers to tonnes of good *i* exported in year *t*. $r_{export,i,t}$ is the ratio of the value per tonne of exports of good *i* in year *t* to the value per tonne in 2000.

However, this method cannot be applied due to data problems. In 2000 it turns out that for some goods categories the exported tonnes (according to the Intrastat and Extrastat database of the INR/ICN) are larger than the tonnes transported from Belgium to the ROW (according to the transport statistics), implying a negative value for transit with transhipment. Until this data issue is resolved, another approach needs to be taken. In PLANET the tonnes transported from Belgium to the ROW ($TON_{BEROW,i,t}$) are therefore determined as follows:

$$TON_{BEROW,i,t} = \frac{VAL_{export,i,t}}{\left(\frac{VAL_{export,i,2000}}{TON_{BEROW,i,2000}}\right) r_{BEROW,i,t}} = \frac{VAL_{export,i,t}}{VALTON_{BEROW,i,2000}\ r_{BEROW,i,t}}$$

$VALTON_{BEROW,i,2000}$ is the value per tonne for transport from Belgium to the ROW in 2000. It is calculated as the ratio between exports and the number of tonnes transported from Belgium to the ROW. $r_{BEROW,i,t}$ is the ratio of the value per tonne of transport from Belgium to the ROW of good *i* in year *t* to the value per tonne in 2000.

Similar problems arise in the case of freight transport from the ROW to Belgium (subscript *ROWBE*). Therefore, the tonnes lifted from the ROW to Belgium are calculated as follows (with similar notation as in the previous case):

$$TON_{ROWBE,i,t} = \frac{VAL_{import,i,t}}{\left(\frac{VAL_{import,i,2000}}{TON_{ROWBE,i,2000}}\right) r_{ROWBE,i,t}} = \frac{VAL_{import,i,t}}{VALTON_{ROWBE,i,2000}\ r_{ROWBE,i,t}}$$

c. Transit transport without transhipment

For the period 2000-2005 transit transport without transhipment in PLANET is based on actual observations. For the period after 2005 it is determined by means of a demand function, where the demand for transit transport through Belgium depends on the level of international trade and the relative transport costs of routes through Belgium and other routes. The impact of the change in the transport costs is taken into account in the Modal and Time Choice module. Here we consider only the impact of the change in the level of international trade. This is approximated by the change in tonnes transported to and from Belgium.

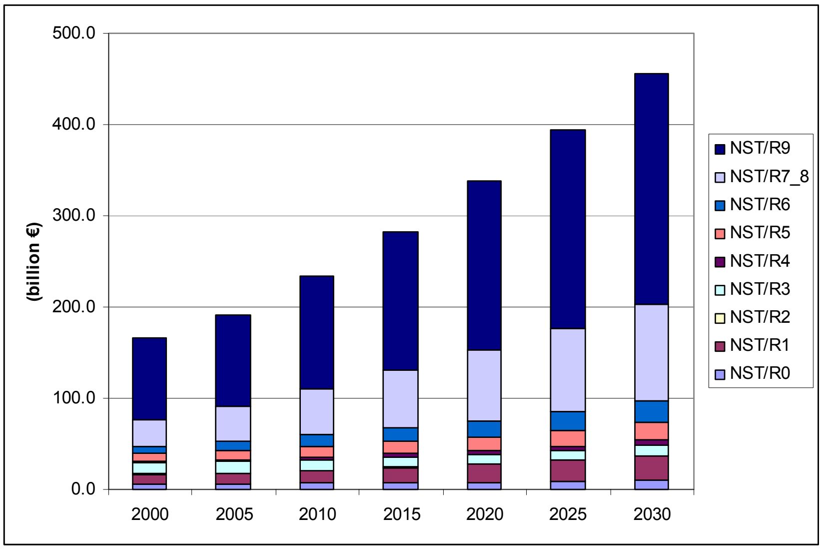
3.2.2. Inputs for freight transport generation

a. Value of production, imports and exports in base year and projection years

The value of domestic production, imports and exports in the base year and in the projection years is taken from the Macro module. Note that, since the projections for domestic production cannot differentiate between the goods categories NST/R7 and NST/R8 and because NST/R7 is a small product category, the PLANET model considers the aggregate of these two categories, denoted by NST/R7_8.

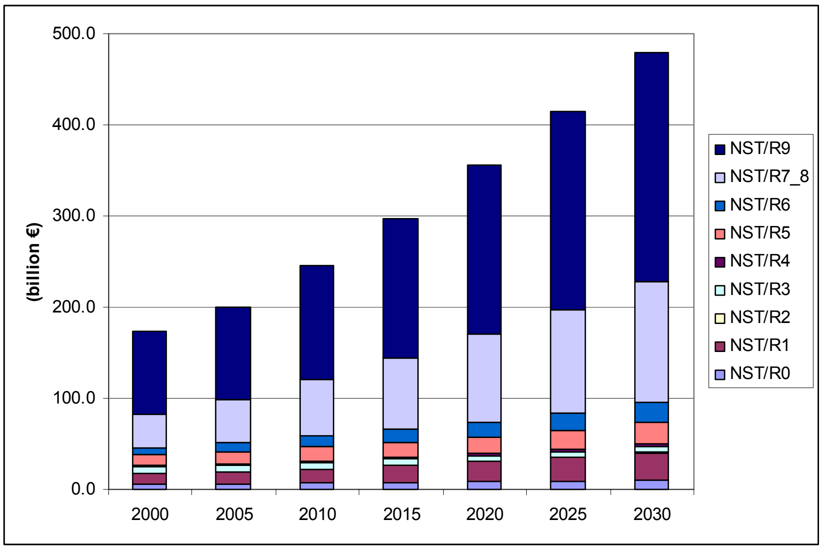
Imports and exports are expected to grow by 3.4% on average per year over the period 2000-2030. The evolution of imports and exports is summarised in Figure 19 and Figure 20.

Figure 19: Projection of import of goods (billion euro - at constant prices of 2000)



Source: Macro module of PLANET

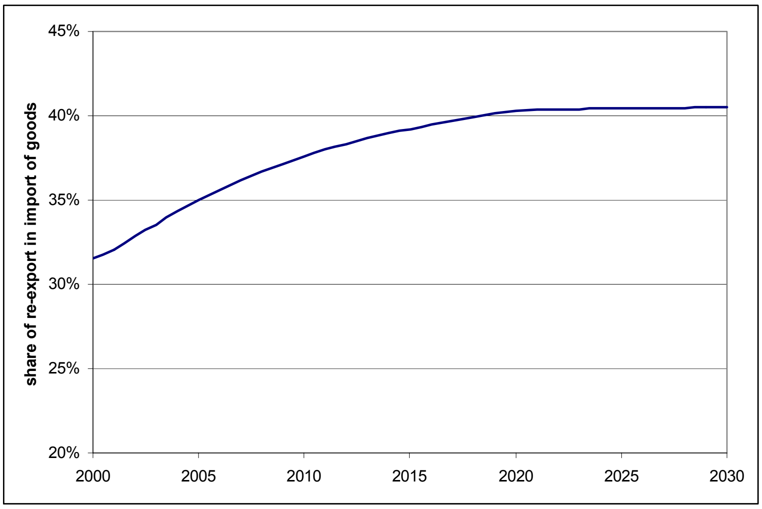
Figure 20: Projection of export of goods (billion euro - at constant prices of 2000)



Source: Macro module of PLANET

For the base year the share of goods that is re-exported immediately after being imported is based on the Use table of imports at constant prices, taken from the EU-KLEMS project. The share is allowed to differ for the different NST/R categories. In 2000 it ranges from 11% for NST/R6Z[37] to 79% for NST/R6D, with an average of 32%. Figure 21 presents the projected evolution of the share of re-exports for the aggregate of all goods. It results from the extrapolation[38] of the trends per NST/R product observed between 1995 and 2002, combined with the projected shifts in the product mix of imports.

Figure 21: The projected evolution of the share of re-exports in the import of goods



Source: Macro module of PLANET

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[37] In the PLANET model NST/R6 is split (given the heterogeneity in this category) between 6Z (building materials) and 6D (precious stones).

[38] Extrapolation under the assumption of decreasing growth rates.

b. Tonnes lifted in the base year

The tonnes lifted in the base year consist of the sum of the tonnes lifted by road (by heavy and light duty vehicles, denoted respectively by HDV and LDV), rail, inland navigation, air, pipeline and maritime transport. The data are taken from the transport indicator database developed by the FPB for the FPS Mobility and Transport. For road LDV Belgian data are scarce. Therefore, a number of assumptions needed to be made, which are briefly described in the next paragraphs.

Freight transport by light duty vehicles

The information about road freight transport by LDV in Belgium is limited. The only data that are available concern the number of LDVs and the average annual mileage per LDV (FOD Mobiliteit en Transport/FPS Mobilité et Transports, 2003). Therefore, we have combined the scarce Belgian data with data from UK surveys[39] on freight transport by company owned and privately owned LDVs to obtain an approximation of the tkm and tonnes transported by LDVs, per NST/R10 goods category. It is an approximation only since the data for the UK are not necessarily transferable to the Belgian situation. It is assumed that all freight transport by LDVs is national. The results are summarised in Table 18 and Figure 22. Table 19 shows that the share of LDVs in national tonnes lifted is non-negligible and that it is quite high for some goods categories.

Table 18: Freight transport by LDVs in 2000

			Based on data for
Number of LDVs	407115	(a)	Belgium
Average annual kilometrage per LDV (km/year)	18701	(b)	Belgium
Million vkm	7613	(c)=(a)*(b)	
Average load factor (tonne/vkm)	0.25	(d)	UK
Million tkm	1903	(e)=(c)*(d)	
Average distance per tonne (km/tonne)	28.97	(f)	UK
Million tonnes	65.71	(g)=(e)/(f)	

Source: FPB on the basis of DIV, FOD Mobiliteit en Transport/FPS Mobilité et Transports (2003) and UK Department for Transport (2004a, 2004b, 2005)

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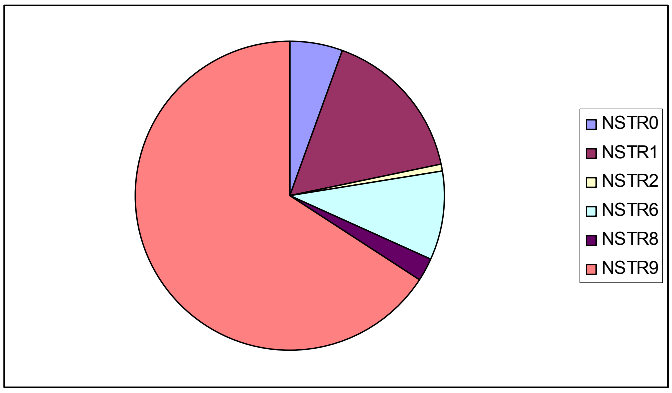
[39] UK Department for Transport (2004a, 2004b, 2005).

Figure 22: Share of NST/R10 chapters in freight transport by LDVs



Source: FPB on the basis of UK Department for Transport (2004a, 2005)

Table 19: Share of LDVs in national tonnes lifted in 2000

NST/R chapter	Share of LDVs in national tonnes lifted
NST/R0	13.3%
NST/R1	20.7%
NST/R2	6.4%
NST/R6	3.8%
NST/R8	7.5%
NST/R9	42.4%
Total	15.0%

Source: FPB on the basis of DIV, FOD Mobiliteit en Transport/FPS Mobilité et Transports (2003) and UK Department for Transport (2004a, 2004b, 2005)

Total tonnes lifted in 2000

Total tonnes lifted in 2000 are presented in Table 20, together with the share of the different goods categories. For transit transport without transhipment, no distinction can be made according to goods type, since this information is lacking for transit transport by road.

Table 20: Total tonnes lifted in 2000 (ktonnes) and share of NST/R categories

Goods category	National		Belgium to ROW		ROW to Belgium		Transit without transhipment
NST/R0	27124	6.2%	10330	4.7%	16045	5.8%	
NST/R1	51796	11.8%	13528	6.1%	18251	6.6%	
NST/R2	7899	1.8%	4808	2.2%	14851	5.4%	
NST/R3	21357	4.9%	22616	10.2%	59150	21.4%	
NST/R4	10959	2.5%	4266	1.9%	19001	6.9%	
NST/R5	25469	5.8%	20003	9.1%	18366	6.7%	
NST/R6	155186	35.4%	29579	13.4%	29804	10.8%	
NST/R7_8	36729	8.4%	28794	13.0%	28954	10.5%	
NST/R9	102262	23.3%	86834	39.3%	71394	25.9%	
Total	438781		220758		275816		36881

Source: database transport indicators, FPB calculations

Note: for transit without transhipment the information by NST/R chapter is available only for rail and inland navigation and not for road transport. PLANET only considers the aggregate of the goods categories in this case.

In 2000 national transport accounted for 45% of tonnes lifted. Transit without transhipment was responsible for 4%. The rest is accounted for by international transport to and from Belgium. 439 Mtonnes were transported nationally. Three goods categories are responsible for approximately 70% of national tonnes lifted: NST/R6, NST/R9 and NST/R1. The dominant role of a small group of NST/R goods is also observed for international transport. Transport from Belgium to the ROW mainly concerns NST/R9 (39.3%), NST/R6 (13.4%), NST/R7_8 (13%) and NST/R3 (10.2%). The same goods categories account for 70% of transport from the ROW to Belgium.

c. Value per tonne in 2000

Table 21 presents the values per tonne that are calculated for national and international transport in 2000 according to the definitions presented in Section 3.2.1. We remind the reader that for international transport these are computed by dividing the value of import (export) by the number of tonnes transported from the ROW to Belgium (from Belgium to the ROW) rather than by the number of tonnes imported (exported).

Table 21: The value per tonne for national and international transport in 2000 (euro/tonne)

Goods category	National	Belgium to ROW	ROW to Belgium
NST/R0	442	534	334
NST/R1	672	920	613
NST/R2	60	38	39
NST/R3	983	327	196
NST/R4	162	215	118
NST/R5	941	582	447
NST/R6	50	270	279
NST/R7_8	1364	1262	985
NST/R9	1437	1051	1263
Average	681	787	602

Source: FPB calculations

d. Past and future development of the real value per tonne

The projections of domestic production, import and export of the Macro module are expressed in constant prices, implying a constant value per unit that is produced or traded. Nevertheless, the value per tonne may still vary if the composition of goods within the NST/R goods categories changes, implying a change in the weight per unit. For NST/R6 this is already taken into account, since the import and export projections make a distinction between precious stones and the other components of NST/R6. This distinction is necessary since NST/R6 is responsible for a large share of tonnes lifted and since the value per tonne of the two subcategories is very different.

Detailed export and import statistics give evidence that also for the other goods categories the real value per tonne has changed over time due to shifts in the product mix. Table 22 presents the evolution of the value per tonne in constant prices for the period 1995-2005, for the aggregate of imports and exports and for the NST/R product categories[40].

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[40] The figures reported in Table 22 are based on data of the Yearbook of Foreign Trade Statistics (NBB). Calculations have been made at the CN-4 level (some 1300 products).

In general we observe a clear increase in the value per tonne in constant prices, both for imports and exports. This evolution is most pronounced for NST/R4, 5, 6Z, 8 and 9. For NST/R0 and 6D the evolution is different for import and export. For NST/R1, 2 and 3 stable to decreasing real values per tonne are found. In the relatively homogeneous category NST/R7 the structural changes are small by definition, resulting in a fairly constant real value per tonne. The overall increase in the real value per tonne was higher for imports than for exports (2.7% per year for imports compared to 1.5% for exports). This difference was, however, entirely due to larger shifts between NST/R 1-digit products at the import side compared to the export side. Keeping NST/R 1-digit shares fixed, the increase in the real value per tonne was almost identical for imports and exports (resp. 0.8% and 0.9% per year).

Table 22: Real value per tonne 1995-2005 (annual average growth rate in %)

NST/R	Imports	Exports
NST/R0	-0.5	0.6
NST/R1	-1.2	0.0
NST/R2	-0.7	-2.8
NST/R3	0.0	-0.7
NST/R4	4.2	2.8
NST/R5	0.3	0.7
NST/R6	1.2	1.1
- *NST/R6D*	0.7	-0.5
- *NST/R6Z*	0.5	2.1
NST/R7_8	1.4	2.7
- *NST/R7*	-0.1	-0.2
- *NST/R8*	0.4	2.1
NST/R9	1.3	0.7
Total	2.7	1.5
Total with fixed NST/R (1-digit) shares	0.8	0.9

Source: FPB calculations on the basis of the Yearbook of Foreign Trade Statistics (NBB)

The findings of Table 22 imply that the assumption of a constant real value per tonne cannot be justified. Therefore, in our projections we make the following assumptions:

- For the period 2000-2005 we use the observed growth rates.
- For international transport the real average annual growth rates in the value per tonne that are found for the period 1995-2005 are applied to the future years. For transport from Belgium to the ROW we apply the growth rate of the real value per tonne for exports, and for transport from the ROW to Belgium we apply that for imports.
- Unfortunately, we do not have the data to construct a table similar to Table 22 for national transport. Therefore, we assume that the average annual growth rate of the value per tonne for exports can be applied to national transport.

The resulting projections of tonnes lifted for national transport, international transport and transit without transhipment are presented in the report about the business-as-usual scenario.

3.3. Passenger transport generation

The aims of the transport generation module for passenger transport can be summarised as follows:

- to determine for each NUTS3 zone the demand for passenger transport in terms of passenger trips or journeys;
- to determine the total number of commuting and school journeys attracted to each zone.

This is done for the period 2000-2030.

The methodology used for the first aim differs for commuting and school transport on the one hand and the other motives on the other hand. It is described in Sections 3.3.1 and 3.3.2. The results are described in a separate report presenting the results of the business-as-usual scenario.

The attraction of future commuting journeys to the NUTS3 zones in Belgium is discussed Chapter 2. As for the school journeys, it is assumed that the share of each NUTS3 zone in total attraction remains the same as in the base year.

3.3.1. Commuting and school journeys

The number of commuting and school journeys produced in a given zone is assumed to be proportional to the number of working people and students living in that zone. The number of employed people and students per zone is taken from the Macro module. However, from the SES2001 we know that the official place of residence does not always correspond with the actual place of residence. This is the case for 0.7% of the working population and 4.1% of the students.

The SES2001 allows us to construct a correspondence matrix for official and actual zone of residence for the working population and students. This matrix is applied to the socio-demographic data of the base year and to the projections for 2005-2030.

The journey rate per employed person and per student is taken from the SES2001. Account is taken of the number of times per week a commuting or school journey is made and of the number of times per day that this happens. Table 23 summarises the findings of the SES2001 for Belgium. It gives the share of the respondents according to the number of commuting and school journeys they make per day and the number of days they travel per week. The data refer to a typical work or school week. The table also computes the average number of journeys per day and the average number of times one travels per week for both trip purposes. If the two dimensions are combined, one arrives at an average of 5.83 journeys per week per working person for commuting and 6.36 journeys per week per student for school transport. These figures take into account "working at home" as a separate travel mode for commuting journeys and include the average number of days per week worked by people who work at home (approximately 4.43 days per week per person who works at home).

Note that up to now we have discussed the journey rates for Belgium as a whole. The SES2001 also allows us to calculate journey rates per NUTS3 zone. In PLANET we apply these zonal journey rates. Moreover, it is assumed that the journey rates remain constant in the future.

Table 23: Commuting and school journeys per day and per week (2001)

	Commuting	School
Journeys/day		
Share of respondents (excl. non-response)		
1	79.4%	68.7%
2	20.6%	31.3%
Average no. of journeys/day/person	1.2	1.3
Days/week		
Share of respondents (excl. non-response)		
1	0.7%	0.8%
2	1.5%	1.2%
3	4.3%	0.9%
4	7.2%	2.7%
5	73.2%	91.7%
6 and more	13.1%	2.7%
Average no. of days/week/person	4.9	4.9

Source: SES2001

3.3.2. “Other” trip purposes

For the projections of the trips for “other purposes” (i.e. all trips except commuting and school trips) we start from the trip rates found in the MOBEL survey (Hubert & Toint, 2002; Desmet et al., 2007). GRT has provided us with information on the trip rates according to sex, age class, socioeconomic status (student, employed, inactive), household type, formation level and availability of a driving license.

The GRT definition of the age classes is slightly different from the ones used for commuting and school journeys, since they refer only to the population of 6 years and older. Therefore, our projections for the “other” trip purposes only refer to this group of the population[41]. Moreover, GRT considers four household types rather than five: single persons, couples, single parents with children and couples with children. They do not consider the “other” household types as a separate group. As in the MOBIDIC project (Desmet et al., 2007) we assume that this group has the same trip rates as couples. Since PLANET does not make a distinction between people according to formation level and ownership of a driving license, we have aggregated the trip rates of GRT over these two criteria. Finally, it should be noted that according to the GRT definition, the trip rates for “other purposes” also include the return trips for commuting and school. Therefore, in PLANET these have to be subtracted from the GRT trip rates in order to avoid double counting.

Table 24 presents the trip rates per sex, age and socio-economic status together with some average trip rates. The trip rates refer to the number of trips for “other purposes” per person per average day and still include the return trips for commuting and school. It can be seen, that, on average, men have a higher trip rate than women, although for the age class 18-59 the opposite is the case. Working persons have a higher trip rate than students or inactive persons. Male students have a higher average trip rate than inactive men, while the opposite is observed for women.

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[41] The number of trips made by the population younger than 6 years can be expected to be relatively small, implying that this assumption is harmless.

Table 24: Trip rates for “other purposes” (trip/person/average day)

		Men			Women		Men	Women
	Job	Student	Inactive	Job	Student	Inactive		
6-17		2.19			1.18		2.19	1.18
18-59	2.29	1.98	2.00	2.64	1.44	2.30	2.22	2.45
≥60	2.62		2.03	1.91		1.52	2.09	1.54
Average	2.31	2.15	2.02	2.62	1.23	1.86	2.19	2.03

Source: own calculations on the basis of GRT

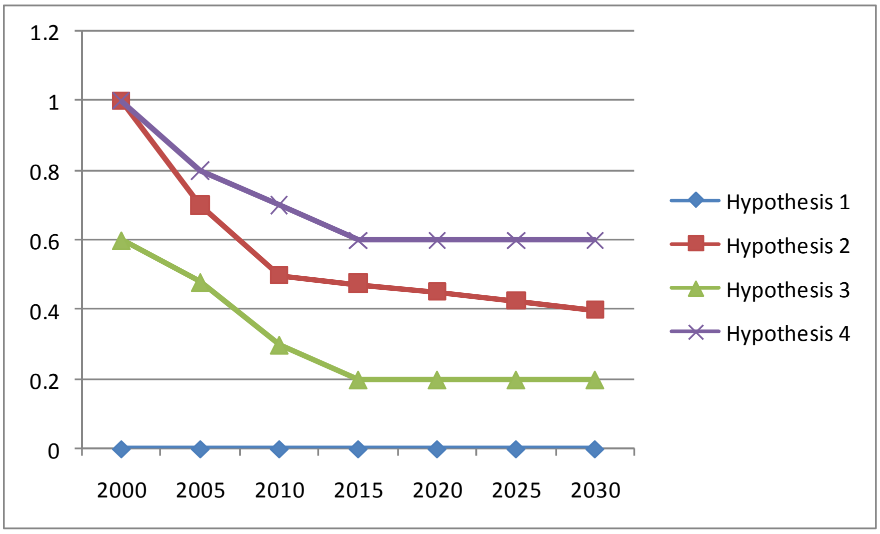
Note: the trip rates include the return trips for commuting and school

The PLANET projections take into account that these trip rates may change in future years due to a change in income (with GDP per capita used as a proxy) and generalised trip costs. In the present module we assume that the generalised costs remain constant. This assumption will be relaxed in the Modal and Time Choice module. Here we only take into account the impact of a change in GDP per capita. We consider four possibilities for the extent to which the trip rates respond to the evolution of GDP per capita (in constant prices). They are summarised in Figure 23.

Hypothesis 1 assumes that the trip rates remain unchanged w.r.t. the base year. This hypothesis is included because the comparison with the other hypotheses allows for a better insight in the impacts of changes in the population versus the change in GDP per capita. Hypothesis 2 is based on the relationship between GDP per capita and passenger transport for “other purposes” that is inferred from the TREMOVE model. It will be used as the central hypothesis. Hypotheses 3 and 4 are respectively the high and low cases for trip growth.

In Hypotheses 2 to 4 the pattern followed by elasticity w.r.t. GDP per capita is similar: it diminishes over time, as can be derived from the TREMOVE results. Moreover, given the reference elasticity of the age class 18-59, we assume that for women in the age classes 6-17 and ≥60 it is 1.2 times higher than the reference elasticity. They are likely to become relatively more mobile in the future, compared to the same classes today.

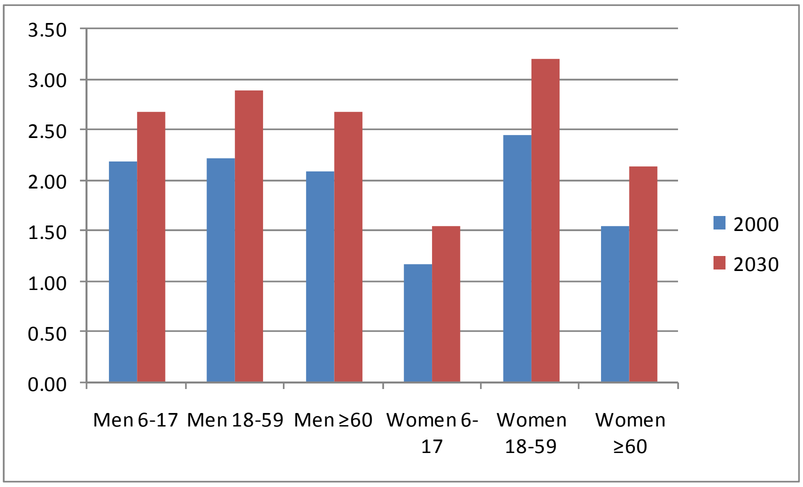
Figure 23: Four hypotheses for the elasticity of the trip rate for "other purposes" w.r.t. real GDP per capita



Note: the figure presents the assumed reference elasticity for the age class 18-59.

The projections for the increase in GDP per capita are taken from the Macro module. Figure 24 presents the resulting change in the trip rates between 2000 and 2030 for Hypothesis 2, per age class and sex.

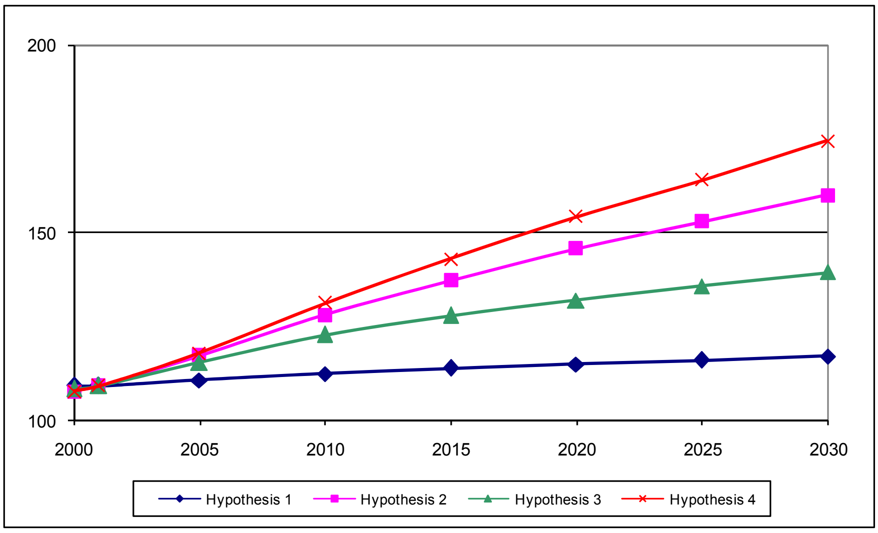
Figure 24: Comparison of trip rates for "other purposes" in 2000 and 2030 (trips/person/average day)



Source: GRT and own calculations

The resulting projections of trips for "other" purposes are presented in Figure 25.

Figure 25: Projected number of trips for "other purposes" according to four hypotheses (million trips per average week)



Source: FPB

First of all, we note that, when keeping the trip rates constant (as in Hypothesis 1), the number of trips is projected to increase, although slightly. With this hypothesis the number of trips increases by approximately 7% between 2000 and 2030. This is due solely to the change in the population and its composition. The other hypotheses take into account the fact that, as the population gets richer, the trip rates rise. As a result of this, the number of trips will increase more rapidly than under Hypothesis 1. The ratio of the trips in 2030 w.r.t. 2000 ranges between 1.29 for Hypothesis 3 and 1.62 for Hypothesis 4. The ratio for Hypothesis 2, which is our central hypothesis, is 1.49. It should be repeated that the hypotheses do not yet take into account changes in generalised trip costs. The impact of these changes will be incorporated in the Modal and Time Choice module.

3.4. Links with the other PLANET modules

The links with the other PLANET modules are summarised in the following two tables:

Table 25 : Inputs in the Transport Generation module of period *t* from the other PLANET modules

	Input from:	Year
- Real value of domestic production, import and export (per goods type) - Share of imports that is re-exported - Real value per tonne (national, Belgium to ROW, ROW to Belgium) per goods type - Population per NUTS3 zone + composition (according to age, sex, household type and socio-economic status) - Working population per NUTS3 zone - Real GDP per capita	Macro	*t*
- Generalised cost of transit tonne trips if passing through Belgium - Generalised cost of trips for "other purposes"	Modal and time choice	*t*-1

Table 26: Output of the Transport Generation module of year *t* to the other PLANET modules

	Output to:	Year
- School and commuting journeys per zone of production - Tonnes lifted per goods type: national, from Belgium to ROW and from ROW to Belgium	Trip distribution	t
- Passenger trips for other purposes - Transit tonnes lifted	Modal and time choice	t

4. The Trip Distribution Module

4.1. Introduction

The aim of the trip distribution module is to construct future production-attraction matrices for commuting and school journeys[42] (in the case of passenger transport) and origin-destination matrices per goods type (in the case of freight transport).

In the literature three families of models are used for trip distribution: growth factor models, discrete choice models and gravity models. Growth factor models are only used in PLANET in a number of cases because they are less suited for the projection exercise that we aim to perform. Indeed, these methods, based on relative growth rates at origins and destinations, are not able to take into account changes in transport costs.

Discrete choice theory is used a lot in recent transport models. However, it is very data intensive and the required information was not available in time for this project, we have opted to use the third approach: the application of gravity models to aggregated data, which are the state of practice for aggregate transport modelling (Ortúzar and Willumsen, 2001).

The structure of the report is as follows. First, the introductory section introduces some definitions. It also gives an overview of the modelling of trip distribution in PLANET and describes some general characteristics of gravity models. Next, Section 4.2 and 4.3 discuss trip distribution modelling for passenger and freight transport, respectively. Finally, Section 4.4 gives an overview of the links of the trip distribution module with the other PLANET modules.

4.1.1. Definitions

First, some terminology needs to be introduced: namely the distinction between production-attraction on the one hand and origin-destination on the other hand. For commuting and school journeys (consisting of a movement from home to the main destination and back) we follow the convention in the literature[43] and assume that the production end always is the home, while the attraction end is the place of work (or school etc.). The origin is the home only for the part of the journey to the place of work (or school, etc.). For the part of the journey that goes back home, home is the destination. For the other passenger trips and for the freight trips the origin corresponds with the place of the production of the trips and the destination corresponds with the place of attraction.

This entails that for the journeys considered in the model the outcome of the distribution module should be transformed from a production-attraction to an origin-destination matrix, before feeding it into the next module, where modal split and time choice are determined (see also Section 4.4).

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[42] A journey corresponds with a movement from home (official or actual) to the main destination and back. In what follows a journey will be assumed to consist of two trips. A trip corresponds with a one-way movement from a given origin to a given destination.

[43] see, e.g., Ortúzar and Willumsen, 2001, p. 124.

The matrix representation of the journeys between production and attraction zones allows for a clearer view of trip distribution modelling. Table 27 presents a standard production-attraction matrix consisting of N zones in which J_{ik} are the journeys between production zone *i* and attraction zone *k*. P_i represents the total number of journeys produced in zone *i* and A_k refers to the total number of journeys attracted to zone *k*. *J* is the total number of journeys. The representation would be similar in the case of an origin-destination matrix.

Table 27: The general form of production-attraction matrix

	Zone of attraction			
Zone of production	1	… *k*	… *N*	$\sum_k J_{ik}$
1	J_{11}	… J_{1k}	… J_{1N}	P_1
.				
i	J_{i1}	… J_{ik}	… J_{iN}	P_i
.				
N	J_{N1}	… J_{Nk}	… J_{NN}	P_N
$\sum_i J_{ik}$	A_1	… A_k	… A_N	$\sum_{ik} J_{ik} = J$

4.1.2. Overview of trip distribution modelling in PLANET

Table 28 summarises how trip distribution will be modelled in PLANET. The model makes a distinction between domestic and international transport. In the case of domestic transport both origin and destination (or production and attraction) lie within Belgium. In the case of international transport the origin (or production) or the destination (or attraction) or both lie abroad. As regards international transport we are mainly interested in the part that takes place in Belgium.

Table 28: Modelling trip distribution in PLANET

		General class of model	Type of model	Input from Transport Generation module
NATIONAL TRANSPORT				
Passenger	Commuting School	Gravity + barrier	Doubly constrained	Journeys with production in zone *i* Journeys with attraction in zone *k*
	Business Other	Trip distribution not modelled		
Freight	All goods types	Gravity + barrier	Unconstrained	National tonnes transported
INTERNATIONAL TRANSPORT				
From Belgium to ROW	Passenger	Growth factor	Attraction constrained	Journeys from Belgium to ROW
	Freight	Growth factor	Unconstrained	Total tonnes transported from Belgium to ROW
From ROW to Belgium	Passenger	Growth factor	Production constrained	Journeys from ROW to Belgium
	Freight	Growth factor	Unconstrained	Total tonnes transported from Belgium to ROW
Transit		Trip distribution not modelled		

In what follows we will describe the modelling approach in more detail. In many cases variants of gravity models are used. Therefore, we start with a brief description of the general characteristics of these models.

4.1.3. Gravity models: general characteristics

Gravity models – more largely called spatial interaction models – originate from the geography literature. The original aim of these models was migration analysis. In the early models geographers have applied the gravitational law of Newton to partly explain migrations. The number of migrants from zone *i* to *k* was assumed to depend on the masses or population (*M*) of the production zone *i* and the attraction zone *k* and on the distance (d_{ik}) between these two zones:

$$T_{ik} = \left(aM_i M_k\right) / d_{ik}^2$$

where *a* is a balancing factor. On this basis more sophisticated models were developed. Good overviews of gravity models are given by Fotheringham and O'Kelly (1989), Immers and Stada (1998, chapter 6), Grasland (2001) and Ortúzar and Willumsen (2001, chapter 5).

The general form of a gravity model can be formulated as follows[44]:

$$T_{ik} = f_1(v_i) f_2(w_k) f_3(c_{ik})$$

where v_i represents a variable measuring the propulsiveness of the origin zone *i*, w_k represents a variable measuring the attractiveness of the destination zone *k*, and c_{ik} represents the variable of separation between *i* and *k*. In order to simplify the presentation of the model we consider here only one propulsiveness variable and one attractiveness variable, even if more than one variable can be used to describe a zone.

In transport models the separation variable c_{ik} may refer to the distance between the two zones, the travel time or the transport costs. Most commonly a combination of the time and monetary transport costs is used. This is referred to as the generalised cost.

Most of the time a power function is used to represent the influence of the site-specific variables:

$$f_1(v_i) = v_i^{\mu} \text{ , } f_2(w_k) = w_k^{\alpha}$$

As for the distribution function, the following functional forms dominate the literature: the power function,

$$f_3(c_{ik}) = c_{ik}^{\beta}$$

and the exponential function,

---

[44] Gravity models can be deduced from several principles. The first is through an analogy with the physical concept of entropy (see Ortúzar and Willumsen (2001, p. 174-178)). However, this approach can be criticised for proceeding by analogy and not from a rigorous reasoning based on assumption and hypothesis. Economics do not play a role. Some economic fundamentals can be identified by the generation of gravity models by means of discrete choice theory (see Quinet and Vickerman (2004, p. 91-92)).

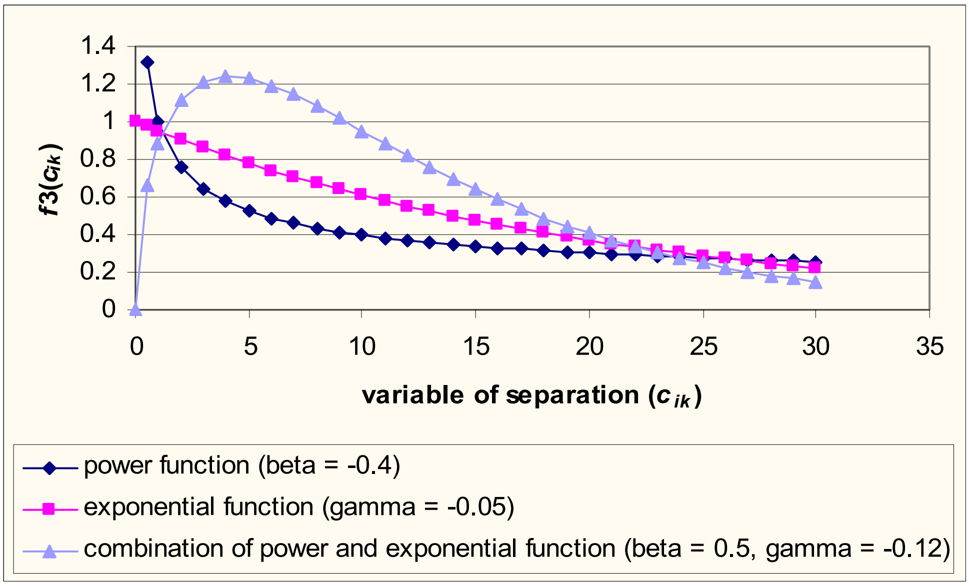
$$f_3(c_{ik}) = e^{\gamma c_{ik}}$$

Sometimes a combination of these two functions is used:

$$f_3(c_{ik}) = c_{ik}^{\beta} e^{\gamma c_{ik}}$$

The typical form of these three functions is presented in Figure 26.

Figure 26: Alternative functional forms for the distribution function



The power function and the exponential function both describe a distribution function that is monotonously decreasing. The exponential function has the disadvantage that the same absolute increase in the variable of separation has the same relative effect on trips at low and at high values of the variable of separation. It is therefore realistic only if one considers small ranges of the variable of separation. The combination of the exponential and the power function allows for a distribution function whose value first rises with the variable of separation and then falls.

Gravity models can be ranked into three families: unconstrained models, singly constrained models (production or attraction constrained) and doubly constrained models. In PLANET we use the doubly constrained model for commuting and school journeys. For national freight transport the unconstrained model is used. Different approaches are used for the different transport flows because the information provided by the Transport Generation module differs across transport segments.

The modelling of trip/journey distribution in Belgium is complicated by the existence of barrier effects due to the linguistic border, as is shown, for example, in a study of Belgian commuting journeys (Dujardin, 2001). Grasland (2001) presents a number of indicators that allow to measure whether such barrier effects are present and describes how they can be dealt with in trip distribution models. Of most interest to our modelling exercise are the integrated models of spatial and territorial interaction. In these models the flows between zones depend both on the separation variable (in our case, the generalised costs) and on whether a given zone-pair belongs to the same region or not. This approach will be discussed in more detail below.

4.2. Passenger transport

4.2.1. Introduction

The aim of the distribution module for passenger transport is to produce production-attraction matrices for commuting and school journeys for the period 2001-2030. These matrices form an input in the Modal and Time Choice module.

The construction of origin-destination matrices for purposes other than commuting and school was not possible due to a lack of data.

For commuting and school journeys we estimate doubly constrained gravity models which take into account barrier effects due to the linguistic border. The general characteristics of such models are described in the next two paragraphs. Afterwards we turn to the calibration of the models.

a. The doubly constrained gravity model

We use a doubly constrained gravity model for the trip distribution of commuting and school transport. In its simplest form the model looks as follows:

$$J_{ik} = a_i b_k f_3(c_{ik}).$$

with

$$a_i = \frac{P_i}{\sum_k b_k f_3(c_{ik})}$$

$$b_k = \frac{A_k}{\sum_i a_i f_3(c_{ik})}$$

J_{ik} is the number of journeys between i and k. P_i is the number of journeys produced in zone i. A_k is the total number of journeys attracted to zone k. c_{ik} refers to the generalised cost of the journey between i and k. The parameters a_i and b_k are balancing factors that ensure that the model reproduces the flows produced in and attracted to each zone:

$$P_i = \sum_k J_{ik} \qquad A_k = \sum_i J_{ik}$$

b. The introduction of barrier effects

In a Belgian context it is important to take into account the presence of barrier effects because of the linguistic border. The simplest way to do so is to introduce a fixed barrier effect which does not depend on the level of the generalised costs. In the case of a doubly constrained gravity model with a power function for the function $f_3(c_{ik})$, the model would be written as follows:

$$J_{ik} = a_i b_k c_{ik}^{\beta} \left(\frac{1}{\gamma} \right)^{Bik}$$

where $B_{ik} = 0$ if i and k belong to the same region, and $B_{ik} = 1$ otherwise. The transport flows that cross the regional barrier then are divided by γ.

However, one can imagine cases where people living close to a barrier respond differently to this barrier than people who live further away. One way to take this into account is to allow for a different generalised cost elasticity for intra- and inter-regional journeys. In the case of the doubly constrained model (with power function) one then obtains:

$$J_{ik} = a_i b_k c_{ik}^{\beta_0 (1 - B_{ik})} c_{ik}^{\beta_1 B_{ik}}$$

The function describing the barrier effect is given by:

$$\zeta(c_{ik}) = c_{ik}^{(\beta_1 - \beta_0)}$$

A smaller value of ζ corresponds with a larger barrier effect. This function equals one if $\beta_0 = \beta_1$. In that case there is no barrier effect associated with crossing the border between regions. If the decay in the interactions as a function of the generalised costs is faster for inter-regional than for intra-regional flows ($|\beta_0| < |\beta_1|$), then the barrier effect tends to increase with the separation variable.

When estimating the gravity model for commuting and school journeys we will test different formulations of the barrier effect.

4.2.2. The estimation of the trip distribution model for commuting and school

a. Methodology

The number of commuting and school journeys between two zones can be seen as count data, taking non-negative integer values only. We can therefore apply count data regression methods to estimate the parameters of the gravity model[45]. Cameron and Trivedi (1998) provide an excellent description of count data regression analysis. The Poisson regression model and the negative binomial model are frequently applied count data models.

In order to ease the presentation of this section, we consider the case of the power function for $f_3(c_{ik})$.

The Poisson regression model

The Poisson regression model is the most common count data regression model. It assumes that, given the value of the explanatory variables, J_{ik} is Poisson distributed with mean parameter λ_{ik}. In the case of the doubly constrained gravity model with a variable barrier effect, λ_{ik} is given by

$$\lambda_{ik} = \exp\left(b_i + h_k + \beta_0 (1 - B_{ik}) \ln c_{ik} + \beta_1 B_{ik} \ln c_{ik} + \varepsilon_{ik}\right).$$

---

[45] Another approach would consist of applying ordinary least squares regression. This approach is discussed in more detail in Fotheringham and O'Kelly (1989) and Grasland (2001).

with $d_i = \ln a_i$ and $h_k = \ln b_k$. B_{ik} is defined in the same way as above. The Poisson model assumes that the conditional mean equals the conditional variance. This characteristic is referred to as equidispersion.

β_0 and β_1 can be interpreted as elasticities. The estimate for β_0 gives the elasticity of the conditional mean with respect to the generalised transport cost for intra-regional journeys. The estimate for β_1 gives the same information for inter-regional journeys.

The estimates for the d_i and h_k ensure that the production and attraction constraints are met for all zones[46].

The assumption of equidispersion underlying the Poisson regression model is not always met and should therefore be tested. One way to do so is to specify a distribution that allows more flexible modelling of the variance than the Poisson. A common model is the negative binomial model, of which the Poisson model is a special case. In that case the presence of equidispersion can be tested by estimating the negative binomial model and testing whether the Poisson hypothesis is valid[47]. The negative binomial model is discussed in the next section.

The negative binomial model

The negative binomial model (see Cameron and Trivedi (1998, p. 70-72) and Greene (2003, p. 744-745)) arises as a modification of the Poisson model in which the mean is μ_{ij}, specified such that:

$$\mu_{ik} = \exp\left(b_i + h_k + \beta_0 (1 - B_{ik}) \ln c_{ik} + \beta_1 B_{ik} \ln c_{ik} + \varepsilon_{ik}\right) = \lambda_{ik} \exp(\varepsilon_{ik})$$

where $\exp(\varepsilon_{ik})$ is assumed to be gamma distributed with mean 1 and variance $\psi = 1/\theta$. The probability that J_{ik} is the number of tonnes transported between i and k is then given by:

$$P(J_{ik}) = \frac{\Gamma(\theta + J_{ik})}{\Gamma(\theta)\Gamma(J_{ik} + 1)} \left(\frac{\theta}{\theta + \lambda_{ik}}\right)^{\theta} \left(\frac{\lambda_{ik}}{\theta + \lambda_{ik}}\right)^{J_{ik}}$$

The model has an additional parameter ψ such that the variance function $\omega_{ik} = \lambda_{ik}(1 + \psi\lambda_{ik})$. The Poisson model is a special case of the negative binomial model (with $\psi = 0$). The null hypothesis that the dispersion parameter is zero can be tested against the alternative that it exceeds zero.

Note that even in case of overdispersion or underdispersion, one can continue to use the Poisson estimated coefficients since "consistency holds for the Maximum Likelihood Estimation (MLE) of any linear exponential family density such as Poisson, provided the conditional mean function is correctly specified" (Cameron and Trivedi, p.63). The estimator obtained is called *Poisson pseudo-MLE (PMLE).* This means that the estimator is like the Poisson MLE, but the data generating process used to obtain the distribution of the estimator need not to be Poisson. One then applies the negative binomial variance function transformation to the MLE variance function to obtain the correct variance matrix.

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[46] This is formally shown in Annex 0.

[47] For other overdispersion tests, the reader is referred to Cameron and Trivedi (1998). These authors also discuss several approaches to handle the overdispersion problem, besides estimating a negative binomial model.

b. Data for the calibration

The calibration of the trip distribution model for commuting and school journeys requires the following information:

- a production-attraction matrix for commuting and school journeys between the Belgian NUTS3 zones for the base year (2001);
- the generalised cost of commuting and school journeys between the Belgian NUTS3 zones in the base year.

This section discusses how this information was obtained. The main source of information is the socio-economic survey of 2001 which provides us with:

- the number of commuting and school journeys between the Belgian NUTS3 zones;
- the average distance of these journeys;
- the average time needed for these journeys.

However, these data need to be checked for all kinds of inconsistencies. The next paragraph briefly discusses how this is done. Next, we describe how the generalised cost of transport is constructed.

The socio-economic survey of 2001

Since we do not have access to the individual data of the SES2001, we use aggregate data at the level of the NUTS3 zones ("arrondissementen/"arrondissements") which were supplied by P. Deboosere and D. Willaert of the VUB. For each Belgian NUTS3 zone and mode of transport the original data set contains the number of journeys per typical school or working week, the average distance and the average travel time of the outward and return trip, to the 43 NUTS3 zones and abroad. 29 combinations of transport modes are distinguished. This means we have 44 * 44 * 29 = 56144 observations. It is taken into account that some people make more than one commuting or school journey per day. The data set also takes into account the number of times per week the journeys are made.

We assigned the 29 combinations of transport modes to six main transport modes. To do so we took into account the order of importance put forward in the SES of 1991: rail, transport organised by school or employer, car (driver and passenger), bus/tram/metro, moped/motorcycle, bicycle and foot. This means that, for example, the combination of rail and car is assigned to rail[48].

A first analysis of the data showed a number of inconsistencies, such as, for example, people commuting on foot from Brussels to Ostend or people travelling at an unrealistically high speed. Therefore, we carried out some checks. We proceeded in two steps. First, we checked the travel distances and made corrections where necessary. In the second step we compared the speed of the different transport modes going from one zone to another. When the average speed exceeded a maximum level, which was defined for each transport mode, the data were adjusted. We also made an adjustment when the average speed was below a minimum level.

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[48] A list of the 29 combinations of transport modes and their codes can be found in Annex 7.6, together with how they are assigned to the transport modes considered in PLANET.

The generalised costs

The generalised cost (*GC*) of commuting and school journeys is the sum of the monetary cost (*MC*) and the time cost (*TC*). The generalised cost depends on the transport mode *m*, the distance between the production zone *i* and attraction zone *k* and the period *p* in which one travels.

$$GC_{ik}^{m,p} = MC_{ik}^{m,p} + TC_{ik}^{m,p}$$

The time costs include costs associated to the time required to get to the main mode, in-vehicle time, walking time and parking time. More details on the calculation of the generalised cost per mode and time period can be found in Chapter 5.

Since the production-attraction matrix refers to the journeys made by all modes and in all periods, the estimation of the matrix requires information on the average generalised cost, defined over all modes and periods. This average generalised cost is taken from the Modal and Time Choice module (Chapter 5) which gives a cost index for the commuting and school journeys between the different zone pairs. This cost index is used as an input in the estimation of the trip distribution model.

For zone pairs with zero commuting journeys, the Modal and Time Choice module does not give a cost index. In these cases, we use the cost index of the zone-pair in the opposite direction if it exists. Otherwise, we combine information on the distance between the two zones with the average cost per km for all zone-pairs.

c. Estimation results for commuting

We now turn to the estimation of the doubly constrained gravity model for commuting. The dependent variable in our estimation exercise is the number of commuting journeys between the NUTS3 zones in Belgium in 2001 for a typical working week. In 2001 the total number of commuting journeys in a typical working week equaled 24.04 million. For 69% of these journeys the zone of production is the same as the zone of attraction. 56% of the journeys take place within Flanders, 25.6% within Wallonia and 7.2% within the Brussels Capital Region. The other journeys cross the border between the regions. For 27.8% of the zone-pairs commuting flows are zero. 2.5% of the zone-pairs account for 75% of commuter flows. The highest commuter flows are recorded within the NUTS3 zone Antwerp (1.8 million journeys per typical working week) and Brussels (1.7 million journeys per typical working week).

The explanatory variables depend on the model that is tested. Several model formulations are compared. They differ in terms of the following characteristics:

- The type of barrier effect: We consider three types of barrier effect: a fixed effect, a variable effect and a combination of the two (see also Section 4.2.1.b). In the first case the model includes a dummy which takes the value zero for intra-regional journeys and one for inter-regional journeys. In the second case the parameters of the cost function are allowed to differ for intra-regional and inter-regional journeys. The last case is a combination of the first two.
- The functional form of the cost function: We compare three formulations of the cost function: the power function, the exponential function and a combination of the two (see also Section 4.1.2)

- The classification of journeys according to the location of production and attraction: The definitions are summarised in Table 29. We make a distinction between 3 types of journeys:
  - Intra-zonal: journeys within the same NUTS3 zone.
  - Intra-regional: inter-zonal journeys that stay within the same region.
  - Inter-regional: inter-zonal journeys that go to a different region.

As regards the intra- and inter-regional journeys we consider 3 definitions:
- Definition 1: All (inter-zonal) journeys that do not cross a regional border are intra-regional, all other journeys are inter-regional.
- Definition 2: All (inter-zonal) commuting journeys, except those between Flanders and Wallonia, are intra-regional. The difference w.r.t. to definition 1 is that journeys that cross the border of the Brussels region are considered to be intra-regional.
- Definition 3: All (inter-zonal) journeys that do not cross a regional border are intra-regional. The inter-regional journeys are divided into two groups: those that cross the border of the Brussels region and those that do not.

Table 29: Alternative definitions of intra-regional and inter-regional journeys

	Same NUTS3 zone?	Definition 1	Definition 2	Definition 3
Flanders-Flanders Wallonia-Wallonia Brussels-Brussels	Yes → Intra-zonal	Intra-zonal	Intra-zonal	Intra-zonal
Flanders-Flanders Wallonia-Wallonia Brussels-Brussels	No → Inter-zonal	Intra-regional	Intra-regional	Intra-regional
Flanders-Wallonia Wallonia-Flanders	No → Inter-zonal	Inter-regional	Inter-regional	Inter-regional 1
Flanders-Brussels Brussels-Flanders	No → Inter-zonal	Inter-regional	Intra-regional	Inter-regional 2
Wallonia- Brussels Brussels-Wallonia	No → Inter-zonal	Inter-regional	Intra-regional	Inter-regional 2

In all models, the explanatory variables include dummies for the zones of production and attraction. For one zone (Philippeville) no attraction dummy is included, in order to avoid the dummy trap.

Table 30 and Table 31 present a selection of the estimation results. For each model, the tables give the estimated values of the coefficients, together with the corresponding t-statistic. The one before last line gives the estimated value of the dispersion parameter (ψ) of the negative binomial model. The last line presents the value of the log-likelihood function.

The first estimation result is that the dispersion parameter is significantly different from zero in all models. Overdispersion is present and, consequently, the negative binomial model rather than the Poisson model is the relevant model for estimating trip distribution.

Models 1 to 3 all assume a combination of a fixed and variable barrier effect and use the same formulation of the cost function: a power function for intra-zonal and intra-regional journeys[49] and a combination of the power function and exponential function for inter-regional journeys. This boils down to the estimation of a negative binomial model with mean:

$$\begin{aligned}\mu_{ik} = {} & \exp(b_i + h_k + \underbrace{\beta_0 (1 - B_{ik1} - B_{ik2}) \ln c_{ik}}_{\text{intra-zonal}} + \underbrace{\beta_1 B_{ik1} \ln c_{ik}}_{\text{intra-regio nal}} \\ & + \underbrace{\beta_2 B_{ik2} \ln c_{ik} + \beta_3 B_{ik2} c_{ik} + \beta_4 B_{ik2}}_{\text{inter-regio nal}} + \varepsilon_{ik})\end{aligned}$$

where B_{ik1} equals one for intra-regional journeys and zero otherwise and B_{ik2} equals one for inter-regional journeys and zero otherwise. Note that in this type of model the elasticity of intra-zonal journeys w.r.t. generalised costs is given by β_0. β_1 gives the elasticity of intra-regional journeys and the elasticity of inter-regional journeys is given by $\beta_2 + \beta_3 . c_{ik}$.

Models 1 to 3 differ in their definition of intra- and inter-regional journeys. Model 1 assumes that only the journeys that stay within the same region are intra-regional (definition 1), while Model 2 also includes journeys to and from Brussels in the intra-regional journeys (definition 2). Model 3 uses definition 3: only the journeys that stay within the same region are intra-regional and the others are divided into two groups: those that involve Brussels as production or attraction zone and those that do not. In most models, the estimated coefficients of the cost function are highly significant and have the expected sign. The coefficients of the production dummies are all significant, while some attraction dummies are not.

The comparison of Models 1 to 3 allows us to investigate the best definition of intra- and inter-regional journeys. Table 28 shows that Model 3 has the highest likelihood value with −5958.94. However, in order to decide whether Model 3 is significantly better than Model 1 or Model 2, we have to perform the Likelihood Ratio (LR) test. The LR statistic is:

$$2(LL_{\text{largest}} - LL_{\text{smallest}}) \sim \chi^2_{(\text{difference in the number of parameters estimated in the two models})}$$

Where LL_{largest} and LL_{smallest} are the largest and smallest log-likelihood of the two models that are compared.

For the comparison between Model 1 and Model 2, the LR statistic equals 7.70. This value should be compared with a Chi-square statistic with degrees of freedom equal to the difference in the number of parameters estimated in the two models. In our case, there is 1 degree of freedom, which corresponds with a Chi-square statistic of 3.84. On the basis of this test we can accept the hypothesis that Model 2 is significantly better than Model 1. This means that all journeys, except those between Flanders and Wallonia, can be considered to be intra-regional. The LR test also shows that Model 3 is not significantly better than Model 2. The value of the LR test statistics equals 0.46 and is smaller that the Chi-square statistic with one degree of freedom (3.84). We therefore choose to use the Model 2 definition of intra-regional and inter-regional journeys. 1.3% of all commuting journeys observed in the socio-economic survey are hence inter-regional.

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[49] Earlier tests have shown that the model performance is not improved significantly if a combination of the power function and the exponential function is also used for the intra-zonal and intra-regional journeys.

Model 2 shows that the incidence of generalised costs of transport is the highest on intra-zonal journeys: the expected number of intra-zonal commuting journeys decreases by 4% if (weighted) generalised costs (ceteris paribus) increase by 1%. This estimated coefficient is significant at the 1% level. The elasticity of intra-regional journeys with respect to generalised costs equals -3.71[50]. Finally, the elasticity of inter-regional journeys is $-3.09-0.01*c_{ik}$ and increases with the level of generalised costs. For this type of journeys, in addition to the variable barrier effect, we also find a significant fixed barrier effect: it equals $\exp(-3.47)=0.03$. This indicates that at a given level of generalised costs, the number of inter-regional journeys is only 3% of the number of intra-zonal and intra-regional journeys. We do not find such a fixed barrier effect for intra-regional journeys: in these cases, the barrier effect depends on the level of generalised costs. Furthermore, the results also indicate that intra- and inter-regional commuters are less sensitive to generalised costs than intra-zonal commuters.

Table 30 provides also evidence that Model 3 reduces to Model 2. In fact, the elasticity of intra-regional journeys is not significantly different from that of journeys that cross the border of the Brussels region[51] with respect to generalised costs. This suggests that journeys that cross the border of the Brussels region can be considered as intra-regional.

Model 4 is included to see whether a different form of the cost function improves the model performance. The difference between Model 4 and Model 2 is that Model 4 assumes a power function. It estimates a negative binomial model with mean:

$$\mu_{ik} = \exp(b_i + h_k + \underbrace{\beta_0(1-B_{ik1}-B_{ik2})\ln c_{ik}}_{\text{intra-zonal}} + \underbrace{\beta_1 B_{ik1}\ln c_{ik}}_{\text{intra-regional}} + \underbrace{\beta_2 B_{ik2}\ln c_{ik}}_{\text{inter-regional}} + \varepsilon_{ik})$$

As can be seen from its log-likelihood value (-5961.2)[52], it performs significantly worse than Model 2.

Next, we analyse whether the model can be improved by considering other definitions for the barrier effect. More particularly, we compare Model 2 with two other models. Both models assume a combination of a power function and exponential function for the cost function and definition 2 for the intra- and inter-regional journeys.

Model 5 considers a fixed barrier effect only, i.e. one that does not depend on the level of the generalised costs. The mean of the corresponding negative binomial model is given by:

$$\mu_{ik} = \exp(b_i + h_k + \underbrace{\beta_0 \ln c_{ik} + \beta_1 c_{ik}}_{\text{all journeys}} + \underbrace{\beta_2 B_{ik2}}_{\text{inter-regional}} + \varepsilon_{ik})$$

The barrier effect of inter-regional journey is significant at the 1% level. It indicates that at a given level of generalised costs, the number of inter-regional journeys is only 100[exp(-1.44)]=24% of intra-zonal and intra-regional journeys. However, Model 5 performs worse than Model 2, with a log-likelihood value of -5970.2.

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[50] Earlier tests have shown that the model performance is not improved significantly if a combination of power function and exponential function is used for intra-regional journeys (Def. 2).

[51] Inter-regional journeys 2, Definition 3, cf. Table 1.

[52] The LR statistic equals 4.1 which is higher than the Chi-square statistic with one degree of freedom.

Model 6 considers a variable barrier effect only. The corresponding mean of the negative binomial model is:

$$\mu_{ik} = \exp(b_i + h_k + \underbrace{\beta_0(1 - B_{ik1} - B_{ik2})\ln c_{ik}}_{\text{intrazonal}} + \underbrace{\beta_1 B_{ik1} \ln c_{ik}}_{\text{intraregional}} + \underbrace{\beta_2 B_{ik2} \ln c_{ik} + \beta_3 B_{ik2} c_{ik}}_{\text{interregional}} + \varepsilon_{ik})$$

Comparing the log-likelihood of this model with that of Model 2, Table 31 shows that Model 6 performs worse. In addition, the LR test confirms that Model 2 is definitely better than Model 6. The value of the LR test statistic equals 26.4 which is larger than the Chi-square statistic with one degree of freedom (3.84).

Table 30: Comparison of commuting trip distribution models with a fixed and variable barrier effect

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Ln(GC*) intra-zonal	-4.07	-39.78	-4.03	-40.35	-4.03	-40.30		
Ln(GC) intra-regional (Def. 1 & 3)	-3.72	-75.32			-3.71	-76.99		
Ln(GC) intra-regional (Def. 2)			-3.71	-77.01			-3.71	-76.95
Ln(GC) inter-regional (Def. 1)	-3.10	-15.94						
Ln(GC) inter-regional (Def. 2)			-3.09	-15.10			-3.48	-44.33
Ln(GC) inter-regional 1 (Def. 3)					-3.1	-15.11		
Ln(GC) inter-regional 2 (Def. 3)					-3.65	-41.81		
GC inter-regional (Def. 1)	-0.01	-2.08						
GC inter-regional (Def. 2)			-0.01	-2.0				
GC inter-regional 1 (Def. 3)					-0.01	-1.99		
Dummy barrier inter-regional (Def. 1)	-3.51	-5.63						
Dummy barrier inter-regional (Def. 2)			-3.47	-5.29			-2.35	-6.43
Dummy barrier inter-regional 1 (Def. 3)					-3.47	-5.30		
Production dummy – Antwerp	18.40	65.90	18.33	66.71	18.34	66.72	18.32	66.73
Production dummy – Brussels	19.0	70.04	17.50	66.19	17.32	46.90	17.49	66.17
Production dummies – other zones**	…	…	…	…	…	…	…	…
Attraction dummy – Antwerp	2.63	14.33	2.63	14.38	2.63	14.38	2.63	14.46
Attraction dummy – Brussels	4.55	24.55	3.10	17.48	2.91	9.18	3.11	17.51
Attraction dummy – other zones**	…	…	…	…	…	…	…	…
Dispersion parameter (ψ)	0.42	20.64	0.42	20.57	0.42	20.57	0.42	20.56
Log-likelihood	-5963.025		-5959.172		-5958.943		-5961.240	

* GC = weighted generalised cost

** Results not reported but available upon request

Table 31: Comparison of commuting trip distribution models with different types of barrier effect

	Model 2		Model 5		Model 6	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Ln(GC*) intra-zonal	-4.03	-40.35			-3.92	-40.00
Ln(GC) intra-regional (Def. 2)	-3.71	-77.01			-3.65	-77.90
Ln(GC) inter-regional (Def. 2)	-3.09	-15.10			-4.12	-66.43
Ln(GC)			-3.34	-39.04		
GC intra-regional (Def. 2)	-0.01	-2.0			0.01	4.17
GC			-0.01	-2.76		
Dummy barrier inter-regional (Def. 2)	-3.47	-5.29	-1.44	-27.67		
Production dummy – Antwerp	18.33	66.71	17.17	54.42	18.12	66.31
Production dummy – Brussels	17.50	66.19	16.33	52.48	17.28	65.87
Production dummies – other zones**	…	…	…	…	…	…
Attraction dummy – Antwerp	2.63	14.38	2.63	14.20	2.65	14.37
Attraction dummy – Brussels	3.10	17.48	3.1	17.18	3.11	17.32
Attraction dummy – other zones**	…	…	…	…	…	…
Dispersion parameter (ψ)	0.42	20.57	0.43	20.73	0.43	20.66
Log-likelihood	-5959.172		-5970.268		-5972.398	

* GC = weighted generalised cost

** Results not reported but available upon request

To conclude, our analysis of Models 1 to 6 shows that Model 2 performs the best. Therefore, we will use this model for the simulation of the trip distribution matrix for the years 2001-2030. Model 2 is a model with a variable and fixed barrier effect, definition 2 for intra- and inter-regional journeys, a power function for the costs of intra-zonal and intra-regional journeys and a combination of the power function and exponential function for the costs of inter-regional journeys.

d. Estimation results for school

We now turn to the estimation of the doubly constrained gravity model for school. The dependent variable is the number of school journeys between the NUTS3 zones in Belgium in 2001 for a typical school week. In 2001 the total number of school journeys in a typical school week equaled 14.04 million. For 86.3% of these journeys the zone of production is the same as the zone of attraction. 54.7% of the journeys take place within Flanders, 32.1% within Wallonia and 9.8% within the Brussels Capital Region. The other journeys cross the border between the regions. For 55.1% of the zone-pairs commuting flows are zero. 1.3% of the zone-pairs account for 75% of commuter flows. The highest commuter flows are recorded within the NUTS3 zone Brussels (1.4 million journeys per typical school week) and Antwerp (1.2 million journeys per typical school week).

Table 32 presents the estimation results for the school journeys. The overdispersion tests reject the hypothesis of equidispersion. They suggest that the variance function $\omega_{ik}=\lambda_{ik}(1+\psi)$ is a multiple of the mean and is not quadratic in the mean like in the commuting model ($\omega_{ik}=\lambda_{ik}(1+\psi\ \lambda_{ik})$). To handle this kind of overdispersion, we estimate a Poisson pseudo-MLE with negative binomial variance function ($\omega_{ik}=\lambda_{ik}(1+\psi)$).

Table 32: School trip distribution model

	Coeff.	t-stat.
Ln(GC[*]) intra-zonal	-3.44	-32.45
Ln(GC) intra-regional (Def. 2)	-3.67	-60.85
Ln(GC) inter-regional (Def. 2)	-3.58	-12.59
Dummy barrier inter-regional (Def. 2)	-2.67	-4.41
Production dummy – Antwerp	13.30	58.28
Production dummy – Brussels	12.85	57.63
Production dummies – other zones[**]	…	…
Attraction dummy – Antwerp	2.52	13.44
Attraction dummy – Brussels	3.57	20.66
Attraction dummy – other zones[**]	…	…
Log-likelihood	-23500.77	

[*] GC = weighted generalised cost

[* *] Results not reported but available upon request

As in the case of commuting journeys we tested several models[53]. Table 32 presents the model that performs best. It is close to Model 2 for commuting journeys. Recall that this model assumes that all school journeys, except those between Flanders and Wallonia are intra-regional. All others are inter-regional. Further, we also find that a model with both a fixed and variable barrier effect is significantly better than models with only a fixed or a variable barrier effect. Finally, our results also suggest that the estimation of the model with a cost function that combines a power and an exponential function does not significantly improve the model performance. We therefore estimate the model with a power function.

The results indicate that the elasticity of intra-zonal school journeys with respect to the (weighted) generalised costs equals -3.44 and is significant at 1% level. The elasticity of the intra-regional and inter-regional journeys with respect to the generalised costs equal -3.67 and -3.58 respectively. These latter elasticities are higher than the elasticity for intra-zonal journeys. As regards inter-regional journeys only, we also find in addition to the variable barrier effect a significant fixed barrier effect: it equals $\exp(-2.67) = 0.07$. This indicates that at a given level of generalised costs, the number of inter-regional journeys is only 7% of the number of intra-zonal and intra-regional school journeys.

4.3. Freight transport

The estimation of trip distribution for freight transport first of all requires the availability of OD matrices in the base year. For the construction of these matrices in 2000 we start from OD matrices for 1995 that were provided to us by STRATEC. The methodology basically involves upscaling the 1995 matrices to the observed aggregate transport flows in 2000. The methodology is described in Section 4.3.1, together with the results.

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[53] See Table A 6 and Table A 7 in Annex 7.7 for a selection of the estimation results. The results presented in Table 32 correspond with those for Model 2 in Annex 7.7.

In Section 4.3.2 we estimate count data models that explain the national freight flows between the different zones in terms of transport prices, the characteristics of the zones, etc.

4.3.1. OD matrices for freight transport in the base year

STRATEC has provided the FPB with OD matrices for freight transport in 1995. These concern three modes: inland waterways, rail and road transport by heavy duty vehicles (HDV). For Belgium the level of geographical detail is the municipal level. For the rest of the world (ROW) the level of geographical detail is the NUTS0, NUTS1 or NUTS2 level, depending on the country that is considered.

The 1995 OD matrices are updated to the year 2000, given information on the aggregate freight transport flows in 2000. Since the available data on the freight flows in 2000 differ according to the mode that is considered, a different methodology is used for each mode. The next paragraphs briefly describe the approaches that are taken for transport by inland waterways, rail, road HDV, air and sea. For road transport by light duty vehicles (LDV) the approach is simpler since we cannot base ourselves on pre-existing OD matrices.

a. Methodology

Inland waterways

The following information is available to upscale the 1995 OD matrices for transport by inland waterways (IWW):

- tonnes transported nationally by IWW in 2000, according to NST/R10 chapter;
- tonnes loaded and unloaded in the Belgian NUTS3 zones in 2000, by NST/R10 chapter;
- tonnes transported from ROW to Belgium, by foreign country/zone of origin and NST/R10 chapter;
- tonnes transported from Belgium to ROW, by foreign country/zone of destination and NST/R10 chapter.

In all cases the data source is NIS/INS (2003). The available data allow us to construct OD matrices by NST/R10 chapter. The geographical level of detail is the NUTS3 level for Belgium, and the NUTS0/NUTS1 level for the ROW[54].

Since the NIS/INS provides separate information on national and international transport, this was taken into account in the construction of the OD matrices for 2000.

National freight transport by IWW

The first step in constructing the national OD matrices for 2000 derives the column and row totals of the OD matrix in 2000, i.e. the total number of national tonnes loaded and unloaded in each Belgian NUTS3 zone. For national freight transport by IWW in 2000 we only know the total tonnes transported, not the place where they are loaded or unloaded. We assume for all goods types that the share of the NUTS3 zones in loading and unloading for national transport remains the same as in 1995. In some cases however, this assumption implies a number of tonnes loaded or unloaded that is higher

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[54] NUTS1 for Germany, Spain, France and the Netherlands, and NUTS0 for the other countries.

than the total tonnes loaded or unloaded. If this situation arises, it is assumed that all tonnes loaded/unloaded in that particular NUTS3 zone have a domestic destination/origin.

Given the row and column totals that are obtained in this way, a RAS procedure is applied to derive the 2000 OD matrices. It should be noted that the RAS procedure can be applied only if the structure of the OD matrices is the same in both years. Therefore, in cases where the row or column totals are nonzero in 2000, while they are zero in 1995, the flows are set exogenously. More specifically, they are assigned to the biggest origin/destination zone (Antwerp).

International freight transport by IWW

For international transport from Belgium to the ROW, the flows leaving each Belgian NUTS3 zone are given by the difference between total loading in the zone and loading with domestic destination. The flows arriving in each foreign zone are taken from the NIS/INS transport statistics. Next, a RAS procedure is applied, with corrections if the OD matrices have a different structure in 1995 and 2000. A similar approach is used for international transport from the ROW to Belgium.

Rail

In order to update the 1995 OD matrices for freight transport by rail, we use the following data for 2000:

- tonnes transported nationally, from Belgium to ROW and from ROW to Belgium, by NST/R10 chapter (NMBS/SNCB, 2000);
- tonnes transported from Belgium to ROW and from ROW to Belgium, by NST/R10 chapter and country of destination/origin (NewCronos).

These data allow us to derive OD matrices for rail transport in 2000, by NST/R10 chapter. The geographical level of detail is that of the NUTS3 zones for Belgium and the NUTS0 level for the ROW.

The national OD matrices for rail transport in 2000 are derived by simply upscaling the matrices of 1995 to the transport levels in 2000.

For rail transport from Belgium to the ROW the tonnes transported taken from NMBS/SNCB (2000) and NewCronos differ. For each goods category the tonnes unloaded in the different foreign countries are derived by applying the country shares of Newcronos to the total number of tonnes transported from Belgium to the ROW according to NMBS/SNCB (2000). Per country and goods category the zones of origin in Belgium are obtained by applying the zonal shares per country and goods category of 1995. In some cases the flows are nonzero in 2000, while they are zero in 1995. In those cases the zonal shares of the largest goods category in 1995 are applied. For Eastern European destinations, the zonal shares for Belgium are known only for the aggregate of these destinations in 1995. We assume that these shares can be applied to the individual countries in 2000.

A similar approach is taken for rail transport from the ROW to Belgium.

Road transport by heavy duty vehicles

The construction of the OD matrices for road transport by heavy duty vehicles (HDV) in 2000 combines the 1995 OD matrices with the following data:

- tonnes transported nationally, from Belgium to the ROW and from the ROW to Belgium in 2000 by NST/R10 chapter (taken from the transport indicator database);
- the national and international OD matrix for road transport by HDV in 2000, for the sum of all goods types (unpublished data provided by NIS).

Both for national and international transport this allows us to derive the column and row totals in 2000 of a matrix in which the rows refer to the zone pairs and the columns to the NST/R10 goods categories. Given these row and column totals for 2000, a RAS procedure is used to complete the cells of this matrix, starting from the matrix of 1995. For some zone pairs the tonnes transported in 2000 are nonzero while they are zero in 1995. In those cases the share of the NST/R10 chapters cannot be derived by means of a RAS procedure and the value of the matrix entries is set exogenously. More specifically, it is assumed that the share of the NST/R chapters then equals their share in total national or international road transport in 2000.

The result consists of OD matrices for road transport by HDV in 2000, by NST/R10 chapter. The geographical level of detail is the NUTS3 level for Belgium and the NUTS0/NUTS1 level for the ROW[55].

Road transport by light duty vehicles

No information is available on the geographical distribution of the flows of road freight transport by LDVs, either at the NUTS1 level or at lower levels. Therefore, we have to make an assumption. First of all, all freight transport by LDVs is assumed to be national.

Secondly, the share of each domestic zone pair (by NST/R chapter) is based on the OD matrices for HDV. However, since this would result in too much long distance transport by LDVs, we adapt the matrices for HDV and take into account only goods transport within a given zone or between neighbouring zones.

Air, pipeline and maritime transport

For air transport the OD matrices from Belgium to the ROW and from the ROW to Belgium are based on data from FPS Mobility and Transport and statistics of the Belgian airports. For the ROW no distinction is made yet between the different countries.

Data on transport by pipeline are taken from FPS Mobility and Transport.

For maritime transport the OD matrices for 2000 are taken from NIS/INS.

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[55] NUTS1 for Germany, France, Italy, the Netherlands and the United Kingdom, NUTS0 for the other countries.

b. Results

Table 33 presents the resulting geographical distribution of the total freight transport flows in 2000 and the share of the different modes for each zone pair. For Belgium the flows are given at the NUTS1 level, while the ROW is considered as an aggregate block. The results are also available at the NUTS3 level for Belgium and the NUTS0 level for EU member states (with the other countries grouped in a ROW aggregate). They are also available per NST/R chapter except for transit without transhipment.

Of the 439 Mtonnes that are transported nationally, almost 60% is transported within Flanders. Another 20% is transported between Flanders and the two other Belgian regions. Road transport by HDV is the dominant mode for all national zone pairs. In most cases road transport by LDV is the second most important mode except for transport between Flanders and Wallonia, where rail occupies the second place.

Table 33: OD matrix freight transport in 2000 and share of freight transport modes

		Brussels	Flanders	Wallonia	ROW
Brussels	Total (ktonnes)	5426	4298	1919	2333
	Maritime				9%
	Air				0%
	Inland waterways	0%	2%	0%	13%
	Rail	0%	0%	2%	12%
	Road HDV	82%	88%	88%	66%
	Road LDV	18%	10%	10%	
Flanders	Total (ktonnes)	6446	265456	36614	178561
	Maritime				38%
	Air				0%
	Pipeline			9%	2%
	Inland waterways	17%	5%	15%	17%
	Rail	2%	2%	22%	8%
	Road HDV	66%	75%	53%	35%
	Road LDV	14%	18%	2%	
Wallonia	Total (ktonnes)	2330	33965	82326	40182
	Maritime				1%
	Air				0%
	Inland waterways	0%	11%	4%	19%
	Rail	9%	15%	5%	16%
	Road HDV	78%	72%	74%	64%
	Road LDV	12%	3%	17%	
ROW	Total (ktonnes)	5172	240419	29918	36881
	Maritime	13%	43%	0%	
	Air	0%	0%	0%	
	Pipeline		11%		
	Inland waterways	31%	17%	40%	10%
	Rail	7%	5%	7%	5%
	Road HDV	49%	23%	52%	85%

Source: FPB

Note: Transport from ROW to ROW refers to transit transport without transhipment that passes through Belgium

Freight transport from Belgium to the ROW is dominated by transport from Flanders to the ROW, which has a share of 81% in the 221 Mtonnes that are transported. For this zone pair maritime and road HDV transport account for resp. 38% and 35% of tonnes transported, followed by inland waterways (17%). In the case of freight transport from Brussels or Wallonia to the ROW road transport is the dominant mode with a share of more than 60%.

The flows from the ROW to Flanders account for 87% of the 276 Mtonnes transported from the ROW to Belgium. Maritime transport accounts for 43% of the flows for this zone pair, followed by road (23%) and inland waterways (17%). In the case of transport from the ROW to Brussels or Wallonia, road HDV transport is the main mode, though its dominance is smaller than for international transport in the other direction.

4.3.2. The estimation of trip distribution models for national freight transport

The trip distribution models for national freight transport are estimated using a similar methodology as in the case of passenger transport. However, in the case of freight transport, we use an unconstrained gravity model to explain the freight flows. The main reason for choosing an unconstrained rather than constrained gravity model is that for future years we do not have a projection of the total number of tonnes arriving and leaving in each NUTS3 zone in Belgium. The only information we have for future years is the total number of tonnes lifted.

A general formulation of an unconstrained gravity model with a power function for the cost function and a variable barrier effect is as follows:

$$T_{ikl} = v_i^{\alpha_l} w_k^{\gamma_l} c_{ikl}^{\beta_{0l}(1-B_{ikl})} c_{ikl}^{\beta_{1l} B_{ikl}}$$

T_{ikl} is the number of tones transported between i and k of goods category l. c_{ikl} refers to the generalised transport cost between i and k for good l. $B_{ikl} = 0$ if i and k belong to the same region, and $B_{ikl} = 1$ otherwise. β_{0l} and β_{1l} are the elasticities of the conditional mean with respect of the generalised transport cost for intra-regional and inter-regional journeys respectively. v_i and w_k represent the characteristics of the origin and destination zone, respectively. α_l and γ_l are the corresponding coefficients.

As in the case of passenger transport, we apply count data regression models (more particularly, the negative binomial model) to estimate the parameters of the gravity model.

a. Dependent variable

We estimate an unconstrained gravity model per NST/R chapter[56]. The dependent variable is the number of tonnes transported by NST/R chapter between the NUTS3 zones in Belgium for the year 2000. The total number of tonnes transported varies between about 20 000 and 30 000 for NST/R3, NST/R5 and NST/R0, 37 000 for NST/R7_8, 52 000 for NSTR/1 to about 102 000 and 125 000 for NST/R9 and NST/R6.

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[56] We did not estimate the model for NST/R2 and NST/R4 due to the small size of the flows for these two categories.

b. Explanatory variables

Generalised cost per tonne lifted

Information on the average generalised cost per tonne lifted, defined over all modes and periods is taken from the Modal and Time Choice module (Chapter 5) which gives a cost index for the freight flows between the different zone pairs. For zone pairs with zero freight flows, the Modal and Time Choice module does not give a cost index. In these cases, we use the cost index of the zone-pair in the opposite direction, if it exists. Otherwise, we combine information on the distance between the two zones with the average cost per km for all zone-pairs.

Characteristics of the NUTS3 zones

The first criterion for the choice of the other explanatory factors is that future projections must be available for them. This restricts the possibilities. Therefore, we have to limit the characteristics of the NUTS3 zones to the following variables: the (logarithm of the) population of each zone of origin and destination, the (logarithm) of the production of the goods category transported in the zone of origin per inhabitant, the (logarithm of the) total production of the goods and services per capita in the zone of destination and two dummy variables for the presence of one of the four main freight ports of Belgium[57] in the zone of origin and/or destination.

Definition of intra- and inter-regional journeys, barrier effects and the cost function

For each goods category, we have compared different models in terms of intra- and inter-regional transport, barrier effects and the functional form of the cost function (see Section 4.1.3 for a detailed presentation of these models). Further, we have introduced a dummy variable indicating whether the freight flows occur between neighbouring zones.

c. Estimation results

Our results for the freight flow distribution are presented in Table 34 and Table 35.

The first result is that the dispersion parameter is significantly different from zero for all goods categories studied. The overdispersion tests suggest that the variance functions are quadratic in the mean. Consequently, we estimate our unconstrained gravity model with the negative binomial model.

Table 34 and Table 35 present the model that performs the best for each goods type[58]. For NST/R0, 5, 6 and 7_8, this model is close to Model 3 for commuting journeys. Recall that this model assumes that all journeys that do not cross a regional border are intra-regional. The inter-regional journeys are divided into those that cross the Brussels border and those that do not. For the other NST/R chapters definition 2 of the interregional journeys performs the best.

Our results suggest that the estimation of the model with a cost function that combines a power and an exponential function significantly improves the model performance for NST/R0, 1 and 3. For the other NST/R chapters we estimate the model with a power function only. For all goods categories un-

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[57] This concerns the following zones: Antwerpen, Brugge, Oostende and Gent.

[58] The full set of estimated models is available upon request.

der study, except NST/R3, a model with a variable barrier effect is significantly better than models with both a fixed and a variable barrier effect. Finally, our results show for all goods categories[59] positive significant relationships between the level of freight flows and characteristics of the NUTS3 zones such as population, production of goods and services per inhabitant or the presence of an important freight port.

Table 34: Results of freight transport flows distribution by NST/R chapter

	NST/R0		NST/R1		NST/R3		NST/R5	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Ln(GC[*]) intra-zonal	-0.73	-3.91	-1.40	-4.64	-0.60	-1.12	-0.94	-3.12
Ln(GC) intra-regional (Def. 2)			-3.01	-6.06	-2.00	-3.58		
Ln(GC) intra-regional (Def. 3)	-1.38	-9.50					-1.42	-12.18
Ln(GC) inter-regional (Def. 2)			-2.62	-5.63	-0.80	-3.39		
Ln(GC) inter-regional 1 (Def. 3)	-2.37	-9.81					-1.59	-14.97
Ln(GC) inter-regional 2 (Def. 3)	-1.66	-9.84					-2.19	-13.52
GC intra-regional (Def. 2)			0.15	4.52	0.09	1.78		
GC inter-regional (Def. 2)			0.07	2.65				
GC inter-regional 1 (Def. 3)	0.13	7.15						
Dummy barrier inter-regional (Def.2)					-2.57	-2.41		
Dummy barrier flows to a border zone	2.00	13.78	2.20	16.92	1.16	4.78		
Ln population in the origin	0.73	10.77	0.88	17.84	1.31	13.82	0.73	9.91
Ln production per capita in the origin of the good category transported	0.51	5.44	0.71	11.87	0.36	6.67	1.43	12.10
Ln population in the destination	0.38	9.16	0.39	8.32	-0.22	-2.79	0.95	13.56
Ln production per capita in the destination of all goods and services	1.37	12.09	1.08	8.22	2.07	8.57	1.82	7.59
Port in the origin			0.50	3.56	1.34	5.66	0.65	2.90
Port in the destination			0.69	4.80				
Dispersion parameter (ψ)	3.31	23.16	2.48	24.15	6.28	15.90	6.21	19.06
Log-likelihood	-4666.65		-5355.57		-2489.25		-3062.32	

[*] GC weighted generalised cost

For example, the results of NST/R9 (Machinery, transport equipment, etc) indicate that the elasticity of intra-zonal and intra-regional freight flows with respect to the (weighted) generalised costs equals -0.30 and -0.76 respectively and are significant at 2% and 1% level. The elasticity of the inter-regional flows (between Flanders and Wallonia) with respect to the generalised costs equals -0.90. Flows that cross the border of the Brussels region are intra-regional for this NST/R chapter. We also find that, all other things being equal, the level of flows between bordering zones represent 2047% (=exp(3.0187)) of the other flows.

As regards the characteristics of the NUTS3 zones, a determinant of the demand of freight transport may be the population living in the zone of production and attraction. Our results show that the expected level of the freight flow increases by 0.53% and 0.68% respectively if the population of the zone of origin and destination rises by 1%. The demand of freight transport may further be determined by

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[59] With the exception of NST/R3 as regards the population in the destination zone.

the industrial environment. We find a highly significant positive impact of the logarithm of production per capita of the good transported for the zone of origin and the logarithm of the production per capita of all goods and services in the zone of destination (for NST/R9 the estimated coefficients are 0.68 and 1.29 respectively). Finally, the demand of freight transport may also be related the existing transport infrastructure such as the presence of an important freight port. For NST/R9, Table 35 indicates that the presence of a port in the zone of origin and destination significantly increases freight flows.

Table 35: Results of freight transport flows distribution by NST/R chapter

	NST/R6		NST/R7_8		NST/R9	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Ln(GC[*]) intra-zonal	-0.98	-5.56	0.57	2.79	-0.30	-2.38
Ln(GC) intra-regional (Def. 2)					-0.76	-7.36
Ln(GC) intra-regional (Def. 3)	-1.89	-18.01	-0.26	-2.16		
Ln(GC) inter-regional (Def. 2)					-0.90	-9.34
Ln(GC) inter-regional 1 (Def. 3)	-1.93	-19.41	-0.50	-4.52		
Ln(GC) inter-regional 2 (Def. 3)	-2.40	-19.24	-0.92	-6.19		
Dummy barrier flows to a border zone	1.15	8.30	1.38	8.82	3.02	23.17
Ln population in the origin	0.52	11.22	0.47	8.10	0.53	12.83
Ln production per capita in the origin of the good category transported	0.58	9.91	1.20	14.63	0.68	11.99
Ln population in the destination	0.68	14.31	0.58	10.23	0.44	11.80
Ln production per capita in the destination of all goods and services	0.65	4.50	0.92	5.37	1.29	11.73
Port in the origin			0.71	4.24	0.64	5.00
Port in the destination	0.38	2.65	0.59	3.35	1.10	8.66
Dispersion parameter (ψ)	2.74	27.03	3.64	21.72	2.08	25.36
Log-likelihood	-6714.52		-4365.91		-6030.03	

[*] GC weighted generalised cost

4.4. Links with the other PLANET modules

Table 36 and

Table 37 summarise the interactions of the trip distribution module with the other modules of PLANET.

Table 36: Inputs in the trip distribution module of year *t*

	Input from:	Year
Passenger transport National: total school and commuting journeys per zone of production Commuting and school journeys from Belgium to ROW and vice versa Freight transport (per goods type) National tonnes lifted Tonnes lifted from Belgium to ROW and vice versa	Transport generation	*t*
Generalised cost of travelling between zone *i* and zone *k*, per trip motive/goods type	Modal and time choice	*t*-1
Characteristics of the origin and destination zones in Belgium for domestic freight trips The number of jobs and the supply of education per zone	MACRO	*t*
Trip distribution of passenger and freight transport from Belgium to ROW and vice versa in base year	Exogenous	

Table 37: Output of the trip distribution module of year *t* to the other modules

	Output to:	Year
O-D matrix - passenger transport: commuting and school (national and international trips) - freight transport: all goods types (national, from Belgium to ROW and vice versa)	Modal and time choice	*t*

Note that, in order to produce an origin-destination for commuting and school trips, the production-attraction matrix that comes out of the trip distribution module needs to be transformed into an origin-destination matrix[60].

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[60] Annex 7.8 illustrates with a simple example how this is done.

5. The Modal and Time Choice Module

5.1. Introduction

In this module the number of passenger trips or tonnes transported between zone pairs is taken as given.

The number of pkm and tkm driven by the different modes and in the different time periods is chosen such as to minimise the generalised costs of realising the exogenously given passenger trips or tonnes transported. The "technology of production" for passenger and freight transport is represented by a nested MCES function. "MCES" stands for modified constant elasticity of substitution. Before describing the nesting structure that will be used, Section 5.2 first discusses the general properties of nested MCES functions. The calibration of these functions is described in Section 5.3.

Transport demand depends on the generalised cost, which is the sum of the monetary and time costs. For road transport the travel time is determined endogenously in the model. This is done by means of a speed-flow function that presents the relationship between road speed and road transport flows. Its calibration is described in Section 5.4.

For the resulting transport flows the Modal and Time Choice module also calculates the environmental impacts and the change in net tax revenue, for a given policy scenario. The environmental impacts concern the emissions of carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2). Furthermore, we consider three greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The emission factors were provided to us by VITO. A more detailed description of these emission factors and their evolution in future years is presented in the report on the business-as-usual scenario.

Section 5.5 summarises the links with the other PLANET modules.

5.2. Nested MCES functions: a general introduction

In a nested MCES structure, at each level *k* (*k*=0,…,*K*) the production components at the next level (*k*+1) are chosen in order to minimise the production costs, given the MCES production technology:

$$Min \quad C_{k,i} = \sum_{j\in i} p_{k+1,j} x_{k+1,j}$$

$$s.t. \quad x_{k,i} = \Phi_{k,i}\left[\sum_{j\in i}\left(\alpha_{k+1,j}\right)^{\frac{1}{\sigma_{k,i}}}\left(x_{k+1,j}\right)^{\frac{(\sigma_{k,i}-1)}{\sigma_{k,i}}}\right]^{\frac{\sigma_{k,i}}{(\sigma_{k,i}-1)}}$$

$x_{k,i}$ is the production component *i* at level *k*. $C_{k,i}$ is the cost of producing component *i* at level *k*. It consists of the input costs of the production components *j* at the next level (*k*+1) that are associated with component *i* at level *k*. $j\in i$ is used to indicate the set of components $x_{k+1,j}$ that are associated with $x_{k,i}$. $p_{k+1,j}$ is the unit price of production component $x_{k+1,j}$. The cost $C_{k,i}$ is minimised given the fact that $x_{k,i}$ is produced according to a MCES function. In this function $\Phi_{k,i}$ is a constant defining the units of measurement. It equals unity at all levels except *k*=0. $\alpha_{k+1,i}$ is a weighting parameter and $\sigma_{k,i}$ is the elasticity of substitution.

Solving this minimisation problem gives rise to the following demand functions:

$$x_{k+1,j} = \frac{x_{k,i}}{\Phi_{k,i}} \alpha_{k+1,j} \left(\frac{p_{k,i}}{p_{k+1,j}} \right)^{\sigma_{k,i}}$$

$p_{k,i}$ is a price index and is defined as follows:

$$p_{k,i} = \left[\sum_{j \in i} \alpha_{k+1,j} \left(p_{k+1,j} \right)^{(1-\sigma_{k,i})} \right]^{\frac{1}{(1-\sigma_{k,i})}}$$

The cost of component *i* at level *k* is then given by:

$$C_{k,i} = x_{k,i} \Phi_{k,i} p_{k,i}$$

Having described the general characteristics of nested MCES functions, we now turn to the application of this approach in the PLANET model. In general, modelling modal and time choice involves the following steps:

- Definition of the nesting structure and calibration of the model
- Simulation: once the parameters of the model are determined, it is used to simulate the future evolution of transport demand, for a business-as-usual scenario and for alternative policy packages.

5.3. Calibration of the modal and time choice module

The calibration of the modal and time choice module involves (i) the definition of the nesting structure of the model and (ii) the choice of the elasticities of substitution, the weighting parameters and the scaling parameters such as to obtain realistic generalised cost elasticities for the base year. This section first discusses the calibration for freight transport and then turns to passenger transport.

5.3.1. Freight transport

The scope of the modal and time choice module for freight transport is road, rail and inland navigation. The evolution of maritime, air and pipeline transport is imposed exogenously, for several reasons. First of all, the information on the price and substitution elasticities for these modes is scarce. Secondly, the substitution possibilities between these and the other modes are limited. PLANET therefore assumes that the maritime, air and pipeline movements are not affected by policy measures on the other modes and vice versa. With this assumption PLANET takes the same approach as, e.g., the TREMOVE model.

As air transport accounts for a very small proportion of all international transport, this assumption is quite innocent in this case. For maritime transport, however, it is not since it accounts for a large proportion of international transport. Moreover, it can be argued that short sea shipping is a substitute for international road, rail and inland navigation. Therefore, in the future it will be analysed whether short sea shipping can be modelled endogenously. This depends on the availability of information on the flows and generalised costs for short sea shipping. The evolution of deep see shipping will however remain exogenous.

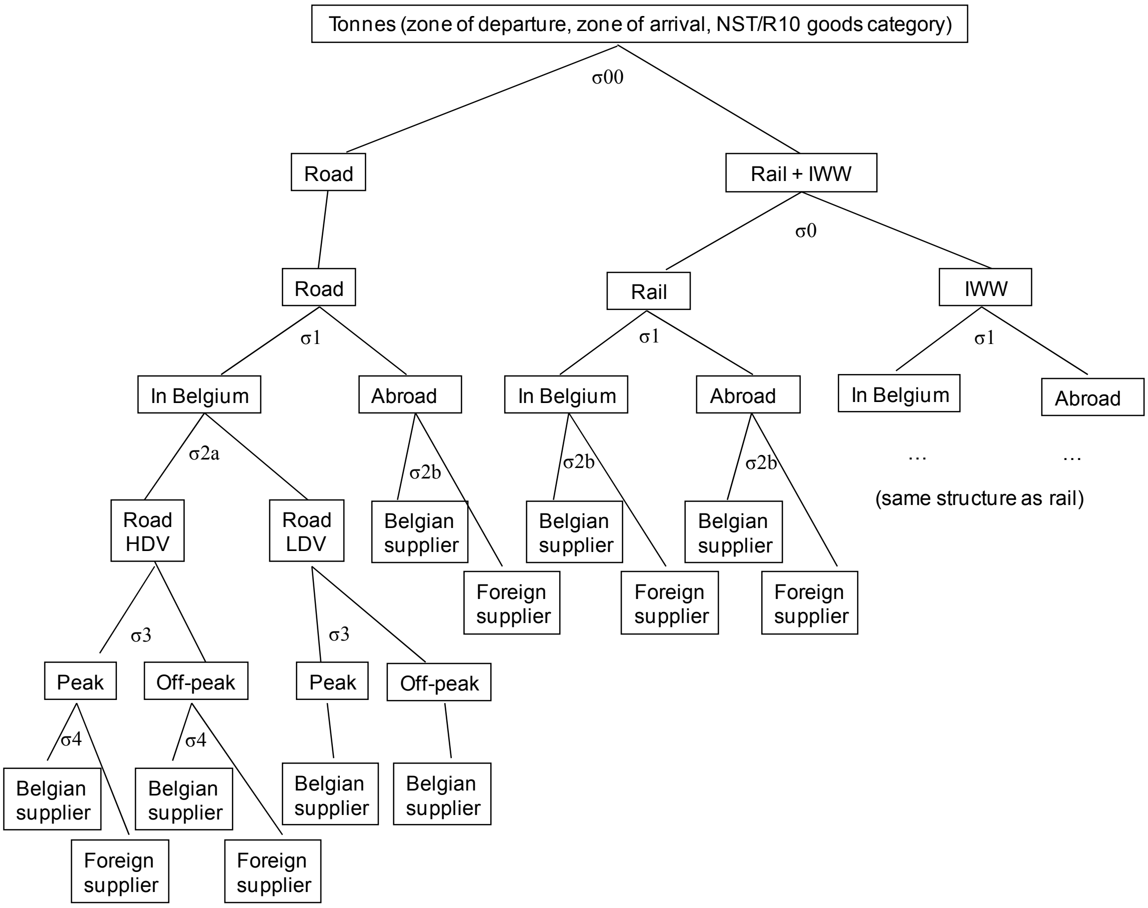
a. Nesting structure

For freight transport the general nesting structure of Figure 27 is used[61]. It is defined for all zone pairs and NST/R chapters. The tonnes transported of a certain goods type between a given zone pair are produced with the input of tkm. A distinction is made between:

- tkm in Belgium and abroad;
- tkm by the following modes: road HDV, road LDV, rail, inland waterways;
- tkm by Belgian and foreign suppliers;
- tkm in the peak and off-peak period (in the case of road transport).

The σ values refer to the elasticities of substitution, which will be discussed in more detail later.

Figure 27: Nesting structure for freight transport



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[61] To simplify the graphical representation of the nesting structure, we dropped the subscripts for the elasticities of substitution. It should be noted that these elasticities may differ according to the zone pair, goods type and branch of the nesting tree that is considered.

It should be noted that not all elements are relevant for all zone-pairs. More particularly:

- in the case of national transport no transport takes place abroad;
- LDVs are assumed to be used only for national transport;
- national rail transport is assumed to be supplied by Belgian firms only.

Finally, for some goods types, some components are not chosen in the base year. The modelling approach implies that they will not be chosen in future years either. The nesting structure imposes a number of limitations on the transport choices. More particularly, elements on a given branch of the tree will react identically to changes in the generalised costs of all elements on the other branches of the tree. For example, a change in the unit costs of rail transport is assumed to have the same impact on all tkm performed by road or IWW, and for transport in Belgium a change in the unit cost of peak transport by road LDV affects road HDV in the peak and off-peak in an identical way.

b. Inputs for the calibration

In the calibration we start from the observed tonnes, tkm and generalised costs per tkm in the base year. The parameters of the nested MCES function are chosen in order to obtain realistic generalised cost elasticities in the reference year. The next paragraphs describe the data used for the calibration. In some cases the data were not available and assumptions needed to be made.

Tonnes transported in base year

For each NST/R chapter the tonnes transported between the zone pairs are taken from the OD matrices for 2000 (cf. Chapter 4).

Tkm in base year

The number of tkm in the base year are derived by multiplying the tonnes transported with the average distance travelled. Table 38 presents the km/tonne in 2000 for the different zone pairs. A distinction is made between transport in Belgium and abroad. The km/tonne for transport abroad is given between brackets.

Table 38 presents averages over the three transport modes. The sources of information for the three modes are described in the next paragraphs.

For road transport by HDV the km/tonne is based on unpublished data of the NIS/INS. The average distances are assumed to hold for all goods types. For national transport the information of the NIS/INS is adjusted such that on average tonnes are transported over a distance of 73.5 km (Gusbin and Hoornaert, 2006). For international road transport the distances travelled in Belgium are taken from Gusbin and Hoornaert (2006).

For road transport by LDV, the average distance per tonne is assumed to be the same for all goods types and equals 29 km/tonne. Its value is based on the UK surveys of freight transport by LDVs (cf. Chapter 4).

For national rail and IWW transport the average distance travelled in Belgium is available per goods type (NMBS/SNCB (2000) and NIS/INS (2003)), but not at the level of the NUTS1 zone pairs. Therefore, we combine this average distance per tonne with information for road transport by HDV on the ratio of the distance per tonne for each zone pair to the average distance per tonne.

For international rail and IWW transport only the average km/tonne in Belgium is known per goods type. No information is available on the distance travelled abroad. We approximate this distance by looking at the distribution of the foreign origins/destinations of rail and IWW transport and by applying the average distance of road HDV transport per foreign origin/destination.

Table 38: Km per tonne in 2000 – in Belgium and abroad (between brackets)

	Brussels	Flanders	Wallonia	ROW
Brussels	46	74	84	104 (354)
Flanders	80	60	130	90 (277)
Wallonia	80	114	50	89 (177)
ROW	97 (315)	92 (217)	93 (167)	146 (n.a.)

Source: FPB on the basis of Gusbin and Hoornaert (2006), unpublished data by INS/NIS, NMBS/SNCB (2000), NIS/INS (2003)

Note: data at a more detailed spatial level are available upon request

For road transport in Belgium the share of the peak period on an average day is taken to be 27% of tkm, based on FOD Mobiliteit en Transport/FPS Mobilité et Transports (2001). The peak period is assumed to correspond with the periods of 7 to 9 AM and 4 to 7 PM on weekdays. The same share of the peak period is assumed to hold for transport by LDV and HDV.

The share of Belgian suppliers in total tkm of the different modes in 2000 is presented in Table 39.

Table 39: Share of Belgian suppliers of tkm in 2000

	Mode	Share of Belgian suppliers
National	Inland waterways	78%
	Rail	100%
	Road HDV	98%
	Road LDV	100%
From ROW to Belgium	Inland waterways	tkm in Belgium: 40% tkm abroad: 23%
	Rail	98%
	Road HDV	52%
For Belgium to ROW	Inland waterways	tkm in Belgium: 45% tkm abroad: 18%
	Rail	98%
	Road HDV	45%
Transit without transhipment (tkm in Belgium)	Inland waterways	35%
	Rail	0%
	Road HDV	14%

Source: Gusbin and Hoornaert (2006), NMBS/SCNB (2000), NIS/INS (2003)

Monetary costs per tkm

For road freight transport the resource costs and taxes per vkm are taken from Hertveldt et al. (2006). To compute the costs per tkm we use the load factors presented in Table 40. For road HDV they are taken from Gusbin and Hoornaert (2006). For road LDV they are based on discussion with the scientific committee of PLANET. In the exercise presented here it is assumed that the resource costs per vkm are the same for Belgian and foreign suppliers. Moreover, they are taken to be the same for all NST/R chapters. Table 41 presents the resulting monetary costs per 100tkm.

Table 40: Load factors for road freight transport in 2000

	Load factor (tonne/vkm)
National	
Road HDV – Belgian supplier	8.6
Road HDV – foreign supplier	11.0
Road LDV	0.25
From Belgium to ROW	
Road HDV – Belgian supplier	12.4
Road HDV – foreign supplier	14.8
From ROW to Belgium	
Road HDV – Belgian supplier	12.1
Road HDV – foreign supplier	12.0
Transit without transhipment	
Road HDV – Belgian supplier	13.2
Road HDV – foreign supplier	11.6

Source: Gusbin and Hoornaert (2006) and discussion with Scientific Committee of PLANET

Table 41: Monetary costs per 1000 tkm – road freight transport (euro/1000tkm)

	euro/1000tkm
National	
Road HDV – Belgian supplier	54.6
Road HDV – foreign supplier	43.0
Road LDV	965.4
From Belgium to ROW	
Road HDV – Belgian supplier	38.1
Road HDV – foreign supplier	38.1
From ROW to Belgium	
Road HDV – Belgian supplier	38.7
Road HDV – foreign supplier	39.4
Transit without transhipment	
Road HDV – Belgian supplier	35.7
Road HDV – foreign supplier	40.5

For rail transport the average monetary cost per tkm is based on the supply and use table. It is determined as follows:

(value of domestic production of good 60A02 + transport margins of sector 60A1)
/tkm transported by NMBS(SNCB)

Good 60A02 refers to freight transport by rail and sector 60A1 to the railway sector. Data from NMBS/SNCB (2000) on the tariff income are used to differentiate this cost per tkm according to the goods types. The result is summarised in Table 42. It is assumed that the monetary cost per tkm is the same for Belgian and foreign suppliers. NMBS/SNCB (2000) indicates that there is a difference between turnover and tariff revenue. This difference is interpreted as government intervention and included in the model as a subsidy, which amounts to 9% of the producer price.

Table 42: Monetary cost per 1000 tkm of rail transport in 2000 (excl. of subsidy)(euro/1000tkm)

Goods category	euro/1000tkm	Goods category	euro/1000tkm
NST/R0	59.4	NST/R5	50.0
NST/R1	53.0	NST/R6	43.9
NST/R2	32.9	NST/R7_8	56.9
NST/R3	31.1	NST/R9	38.2
NST/R4	33.1	Average	43.0

Source: FPB on the basis of NMBS/SNCB (2000)

For IWW the monetary cost per tkm in 2000 is calculated on the basis of the supply and use table for that year. It is determined as follows:

(value of domestic production of good 61B02 + transport margins of sector 61B1)
/tkm transported by Belgian ships on inland waterways

Good 61B02 refers to freight transport by ship on inland waterways and sector 61B1 to inland navigation. The tax per tkm is assumed to be zero. The resulting monetary cost per tkm is 20.3euro/1000tkm. It is assumed that this cost is the same for Belgian and foreign suppliers.

Time costs per tkm

Koopmans and de Jong (2004) provide information on the value of time for the modes considered in PLANET. This publication makes a distinction between different goods types for road transport. Since the correspondence with the NST/R chapters of PLANET is not one to one, we have used a transformation table to derive the average value of time (VOT) per goods category for road transport. Koopmans and de Jong (2004) also give a value of time (per mode) per percentage change of the share of deliveries that arrives too late. If data are available on the share of late deliveries in the base year – which is currently not the case – this could be incorporated in PLANET.

The values of time of Koopmans and de Jong (2004) are expressed in euro/transport/hour. To transform them in euro/tonne/hour, information about the number of tonnes per transport is required. For road transport by HDV this is taken from Gusbin and Hoornaert (2006). For road LDV we based ourselves on Koopmans and de Jong (2004). For rail and IWW the information is based on NMBS/SNCB (2000) and NIS/INS (2003). For rail and IWW the different steps that are taken and the resulting value of time in euro/tonne/hour are presented in Table 43. Table 44 gives the information used to derive the VOT for road transport.

Table 43: The value of time for freight transport by inland navigation and rail

	Value of time (euro/transport/h)(Koopmans and de Jong, 2004)			
Inland waterways	74			
Rail	918			
Tonne/transport	National	From Belgium to ROW	From ROW to Belgium	Transit
Inland waterways	908	557	691	426
Rail	419	419	419	419
Value of time (euro/tonne/h)	National	From Belgium to ROW	From ROW to Belgium	Transit
Inland waterways	0.18	0.13	0.11	0.17
Rail	2.19	2.19	2.19	2.19

Table 44: The value of time for road freight transport

	Value of time (euro/transport/h)(Koopmans and de Jong, 2004 & transformation table)			
Road HDV	NST/R0	45	NST/R5	49
	NST/R1	42	NST/R6	38
	NST/R2	38	NST/R7_8	46
	NST/R3	38	NST/R9	40
	NST/R4	38		
Road LDV	NST/R0	25	NST/R6	21
	NST/R1	23	NST/R7_8	25
	NST/R2	21	NST/R9	22
Tonne/transport	National	From Belgium to ROW	From ROW to Belgium	Transit
Road HDV	12.9	16.7	15.4	13.6
Road LDV	0.56			

As regards the time needed per tkm, for road transport PLANET assumes that the speed of HDV and LDV is resp. 77% and 100% of car speed. The figure for HDV equals the ratio of truck to car speed that was observed on highways in 2000 (FOD Mobiliteit en Transport/FPS Mobilité et Transports, 2001). As regards the level of car speed, we refer to Section 5.4.

Speed of road transport abroad is taken to be 70 km/h. For rail transport in Belgium and abroad we assume a speed of resp. 30 km/h and 55 km/h, as suggested by the follow-up committee. The average speed of IWW is taken to be 10 km/h, on the basis of De Borger and Proost (2001) and as confirmed by the Scientific Committee.

The time cost per tkm is obtained by multiplying the time needed per tkm by the value of time.

Generalised cost elasticities

Table 45 presents an overview of the elasticities of substitution in the nested MCES functions for freight transport. The table uses the same symbols as Figure 27.

σ_{00}, the elasticity of substitution between road and the rail&IWW composite is taken to be larger for international than for national transport. It is taken to be the largest for goods categories that are transported in bulk and for NST/R9 that is transported relatively more in containers.

σ_0, the elasticity of substitution between rail and IWW is assumed to be larger for international transport than for national transport.

σ_1, the elasticity of substitution between transport in Belgium and transport abroad, is relevant only for international transport (excl. transit without transhipment[62]). It is taken to be very low given the limited possibilities to switch between transport in Belgium and abroad when the origin or destination of the freight flows is located in Belgium.

σ_{2a}, the elasticity of substitution between road HDV and LDV, is relevant only for national road transport, since LDVs are assumed to be used for national transport only. The substitution possibilities are taken to be the largest for the goods categories for which LDVs have a relatively large share in the base year (NST/R1 and NST/R9).

σ_3 is the elasticity of substitution between peak and off-peak road transport in Belgium. It is taken to be larger for international than for national transport. Furthermore, it is assumed that the delivery constraints are less flexible for some goods than for others, resulting in a lower value for the elasticity.

Finally, σ_{2b} and σ_4 give the substitution possibilities between Belgian and foreign transporters. This is assumed to be quite high in all cases, implying that transport users do not give a lot of importance to the nationality of the supplier (at a given level of generalised costs). Table 46 to Table 48 present the calibrated generalised cost elasticities used in PLANET.

Table 46 refers to national transport, while Table 47 and Table 48 refer respectively to transport from Belgium to the ROW and transit without transhipment. Comparison with values from the literature is not always straightforward since the concepts that are used are not always comparable with the ones used in the PLANET model. Looking at the aggregate elasticities w.r.t. total costs of Beuthe et al. (2001) we note that the elasticities in the PLANET model are lower. However, the elasticities of Beuthe et al. (2001) should be seen as long-run elasticities, and therefore lower elasticity values seem to be justified.

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[62] Note that the elasticity of total transit without transhipment in Belgium w.r.t. generalised costs in Belgium is taken into account in the Transport Generation module (see Chapter 3).

Table 45: The elasticities of substitution in the nested MCES functions for freight transport

	Elasticity of substitution between	Type of transport	NST/R goods category	Value
σ_{00}	Road, Rail+IWW	National	0,1	1.2
			Others	2
		International	0,1	2.5
			Others	3.5
		Transit	All	4
σ_0	Rail and IWW	National	All	2
		International	0,1	2
			Others	3
σ_1	Transport in Belgium and transport abroad	Belgium to ROW &	All	0.11
		ROW to Belgium	All	0.11
σ_{2a}	Road HDV and road LDV	National road transport in Belgium	2,6,7_8	0.2
			0	1.1
			1,9	2
σ_{2b}	Belgian and foreign transport suppliers	Road abroad	All	5
		Rail	All	5
		IWW	All	5
σ_3	Peak and off-peak	Road LDV and HDV in Belgium (National)	0,1,5,9	0.7
			2,3,4,6,7_8	1.2
		Road HDV in Belgium (Belgium to ROW and ROW to Belgium)	0,1,5,9	1.4
			2,3,4,6,7_8	2.4
		Road HDV in Belgium (transit)	All	2
σ_4	Belgian and foreign transport suppliers	Road HDV in Belgium	All	5

Table 46: Calibrated own generalised cost elasticities of national freight transport

NST/R	Road HDV		Road LDV		Rail	IWW
	Peak	Off-peak	Peak	Off-peak		
0	-0.55	-0.42	-0.59	-0.48	-0.36	-0.90
1	-0.66	-0.62	-0.62	-0.54	-0.55	-1.17
2	-0.92	-0.64	-0.84	-0.43	-0.56	-1.00
3	-0.82	-0.46			-0.37	-0.90
4	-0.86	-0.54			-0.26	-1.46
5	-0.50	-0.32			-0.30	-1.39
6	-0.82	-0.44	-0.86	-0.32	-0.88	-1.32
7_8	-0.86	-0.48	-1.03	-0.86	-1.05	-1.54
9	-0.70	-0.70	-0.53	-0.34	-0.49	-1.98
Average	-0.74	-0.52	-0.59	-0.41	-0.42	-1.24

Table 47: **Calibrated generalised cost elasticities of freight transport from Belgium to ROW**

NST/R	Road in Belgium		Road abroad	Rail		IWW	
	Peak	Off-peak		in Belgium	Abroad	In Belgium	Abroad
0	-0.95	-0.56	-0.13	-0.65	-0.60	-0.53	-1.42
1	-0.95	-0.54	-0.10	-0.57	-0.49	-0.35	-1.60
2	-1.70	-1.05	-0.63	-0.55	-0.87	-0.18	-0.73
3	-1.82	-1.29	-0.89	-0.63	-0.37	-0.17	-1.08
4	-1.63	-0.92	-0.30	-0.36	-0.45	-0.28	-0.79
5	-1.05	-0.75	-0.70	-0.61	-0.75	-0.60	-1.47
6	-1.68	-1.03	-0.20	-0.81	-1.06	-0.79	-0.82
7_8	-1.02	-0.69	-0.56	-1.04	-1.06	-0.36	-1.88
9	-1.00	-0.64	-0.42	-0.58	-0.38	-0.28	-1.98
Average	-1.14	-0.73	-0.40	-0.65	-0.56	-0.54	-1.37

Table 48: **Calibrated generalised cost elasticities of transit without transhipment**

NST/R	Road in Belgium		Rail in Belgium	IWW in Belgium
	Peak	Off-peak		
Total	-1.44	-0.95	-3.43	-3.17

5.3.2. Passenger transport

a. Nesting structure

For passenger transport the general nesting structure of Figure 28 is used. It is defined for all zone pairs and motives. For motives other than commuting and school, no distinction is made according to zone pair, due to a lack of data. The trips for a given zone pair are produced with the input of passenger kilometres (pkm). A distinction is made between:

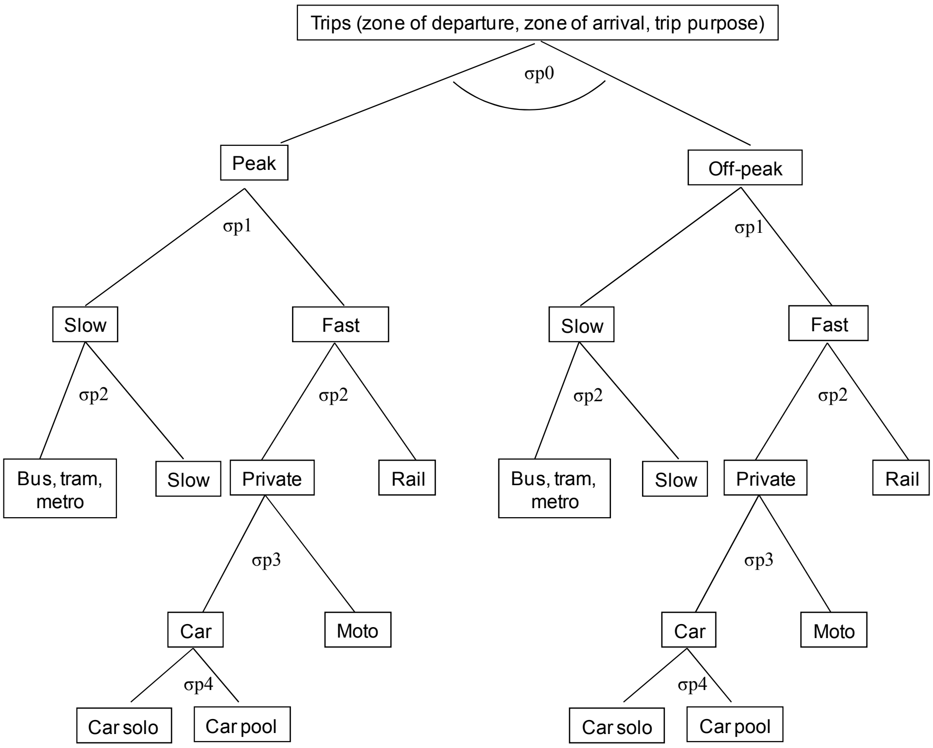
- pkm by the following modes: car solo, car pool, slow, rail, motorcycle and BTM (Bus, Tram, Metro);
- pkm in the peak and off-peak period.

For some zone pairs, some modes are not chosen in the base year. The modelling approach implies that they will not be chosen in future years either. The σp symbols refer to the elasticities of substitution which will be discussed in more detail later.

The nested MCES function is represented by a tree with 5 levels. The top level of the tree represents the total number of trips, per motive and zone pair as a MCES function of components at the next level (peak or off-peak). These components are each in turn a function of a separate group of components, “slow” or “fast”. The “slow” component refers to pkm travelled by bicycle or on foot on the one hand and by BTM on the other hand. The “fast” component is a function of private and rail transport. The private component is a function of car and motorcycle pkm. For car pkm a distinction is made between car solo and car pool.

As in the case of freight transport, the nesting structure imposes a number of limitations on the transport choices. For example, a change in the unit cost of peak transport affects all transport modes in the off-peak period in an identical way.

Figure 28: Nesting structure for passenger transport



b. Inputs for the calibration

In the calibration we start from the observed trips, pkm and generalised costs per pkm in the reference year. The parameters of the nested MCES function are chosen such as to obtain realistic generalised cost elasticities in the base year. The next paragraphs describe the data used for the calibration. In some cases the required data are not available and assumptions needed to be made.

Passenger kilometres in base year

For commuting and school the trips between the zone pairs are taken from the OD matrices for 2001, based on the socio-economic survey of 2001. For the other motives the number of trips is based on MOBEL. In this case however, no information exists on the trip distribution. Consequently, we do not make a distinction between zone pairs in Belgium for these trips.

Monetary costs per pkm

The resource costs and taxes per vkm are taken from Hertveldt et al. (2006). To compute the costs per pkm we use the occupancy rates presented in Table 49. For BTM they are based on the transport indicator database. The occupancy rates for car pool are own calculations based on the average car occupancy rates for school and commuter traffic.

Table 49: Occupancy rates for passenger transport in the base year

	Car solo	Car pool	Bus, tram, metro		Moto
			Peak	Off-peak	
Commuting	1	2.30	37	17.80	1
School	1	2.86	37	17.80	1
Other	1	2.80	37	17.80	1

Time costs per pkm

The value of time, VOT, denotes the exchange rate at which a traveller is indifferent between marginal changes in the time and monetary cost involved in travel. Monetary values for travel time have been applied as an input in many forecasting studies, allowing time and cost to be expressed in common units of “generalised cost”. The literature contains many VOT studies. We make use of a survey conducted in the HEATCO project (Bickel et al., 2006).

The VOT of our baseline model is shown in Table 50. The values of time are expressed in euro/passenger/hour. For car pool 80% of the VOT for car solo was recommended. The VOT for slow is an average of the VOT of car solo, car pool, train and BTM. We assume that the VOT of a motorcyclist is the same as for car solo.

Table 50: VOT in euro/passenger/hour in base year

Mode	Commuting	School and other
Car solo	7.40	6.20
Car pool	5.92	4.96
Train	7.40	6.20
BTM	5.32	4.46
Slow	6.51	5.46
Motorcycle	7.40	6.20

Source: Bickel et al. (2006) and own calculations

The values presented in Table 50 are for expected in-vehicle travel time. Evidence suggests that the changes in walk and wait time are valued more highly than changes in in-vehicle time. Based on Nellthorp et al. (2001) in-vehicle time values should be multiplied by a factor of 1.6 to obtain the value of walking and waiting time.

For trips done by more than one transport mode we had to make an assumption on the distance and speed of the second transport mode. We assume a speed of 4 km/h for transport on foot, 12.5 km/h for transport by bicycle and 35 km/h for trips on a longer distance. We assume a distance for the second mode of 750 metres if the second mode is a bicycle, 500 metres when it is BTM and 4 km when the car is the second mode. For trips by car pool we assume that the average distance to the place of departure equals 100 metres.

Generalised cost elasticties

The production functions are nested MCES functions – hence, we assume constant elasticity of substitution at each level of the tree. This implies that at each branch of the tree an elasticity of substitution must be specified. These elasticties of substitution are explicitly present in the production functions and are determined outside the model (exogenously fixed parameters).

The parameters of the MCES are calibrated such that realistic generalised cost elasticities are obtained. Table 51 presents the elasticities of substitution that are used in PLANET. The same symbols are used as in Figure 28.

Table 51: Overview of the elasticities of substitution for passenger transport

	Elasticity of substitution between	Commuting	School	Other purposes
σp_0	Peak and off-peak	0.55	0.2	1.5
σp_1	Fast and slow modes	0.55	0.25	1.5
σp_2	Private and rail transport	5	5	5
	Slow and BTM transport	7	8 (peak); 7 (off-peak)	5
σp_3	Car and moto	2.5	1.5	3
σp_4	Car solo and car pool			
	Peak	4.5	1.5	4
	Off-peak	4	1.5	5

The resulting calibrated fuel price elasticities are presented in Table 52. They are in line with the literature review made in the European TRACE project (de Jong et al., 1999), as reported in Table 53. The calibrated fare elasticities of public transport are given in Table 54.

Table 52: Calibrated fuel price elasticities

		Car solo	Car pool	Motorcycle
Commuting	Peak	-0.11	-0.45	-0.23
	Off-peak	-0.13	-0.41	-0.22
School	Peak	-0.22	-0.06	-0.12
	Off-peak	-0.20	-0.06	-0.13
Other purposes	Peak	-0.48	-0.30	-0.26
	Off-peak	-0.34	-0.34	-0.29

Table 53: Survey of transport elasticities*

	Commuting	School
Train	-0.50 to -0.69	-0.50 to -0.69
BTM	-0.20	-0.30
Car solo	-0.20	-0.32

* fare elasticities for public transport and fuel price elasticities for car

Source: TRL and own calculations based on TRACE

Table 54: Calibrated fare elasticities

		Bus, tram, metro	Rail
Commuting	Peak	-0.21	-0.43
	Off-peak	-0.34	-0.52
School	Peak	-0.21	-0.34
	Off-peak	-0.34	-0.42
Other purposes	Peak	-0.44	-1.16
	Off-peak	-0.63	-1.51

5.4. Speed flow relationship

The current version of the model assumes one speed-flow relationship for all road transport in Belgium. It is used to determine average car speed in the peak and the off-peak period. To keep things simple, we use a linear relationship. It is calibrated for the car speeds presented in Table 55. From FOD Mobiliteit en Transport/FPS Mobilité et Transports (2001) we know that in 2000 average car speed on highways was 103 km/h. In Table 55 we summarise the assumptions that are made to derive average car speed in the peak and off-peak period for all road types taken together. The values that are imposed exogenously are underlined. The other values refer to the speeds that are derived, given these exogenous assumptions and the share of car traffic in the peak and off-peak period and on the different road types.

Table 55: Assumptions for deriving average car speed in 2000

	Speed (km/h) and share in car vkm (between brackets)			
	Highways	Other numbered roads	Municipal roads	All roads
Peak	75 (9%)	46 (13%)	25 (9%)	40 (31%)
Off-peak	120 (23%)	73 (31%)	45 (16%)	72 (69%)
Average	103 (32%)	62 (44%)	35 (25%)	58

Source: FOD Mobiliteit en Transport/FPS Mobilité et Transports (2001) and own assumptions

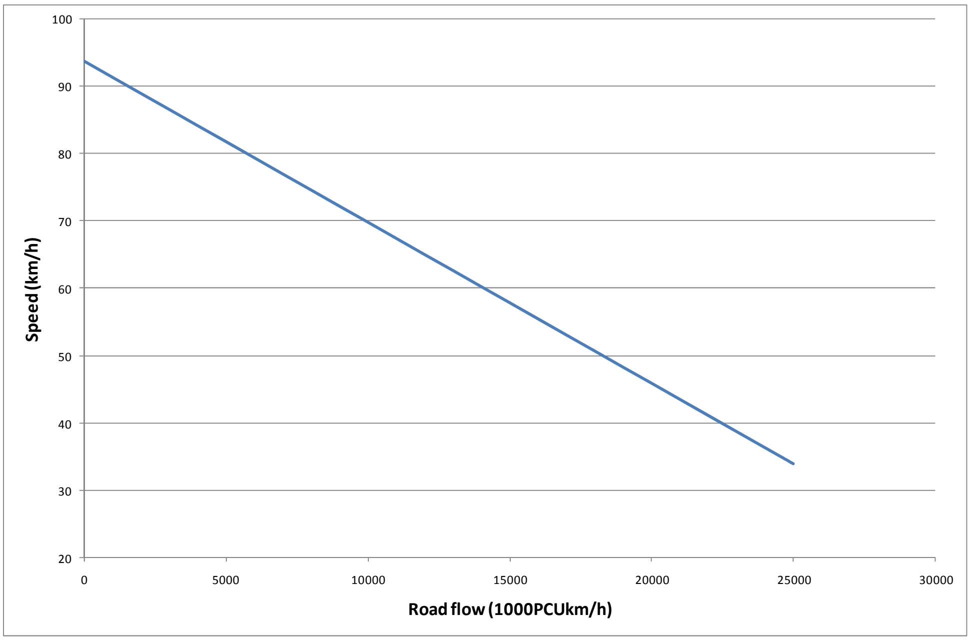
Table 56 presents total vkm driven in the base year by the different vehicle types in the peak and off-peak period. The peak period is assumed to last 3.6 hours on an average day (averaged over weekdays and days in the weekend). A vkm driven by a LDV is taken to be equivalent to 1.5 vkm driven by a car in terms of its impact on congestion. A bus and a HDV are assumed to be equivalent to 2 cars. The resulting calibrated speed-flow relationship is presented in Figure 29. It gives the relationship between car speed (in km/h) and vkm of passenger car units (PCU) per hour per day.

Table 56: Annual vkm driven by different road vehicle types in 2000 (in million vkm)

	Peak	Off-peak
Car + motorcycles	23458	52288
Road LDV	2032	5496
Road HDV	1194	3229
BTM	103	133
Others	19	42

Source: FOD Mobiliteit en Transport/FPS Mobilité et Transports (2001) and own assumptions

Figure 29: Speed-flow relationship



5.5. Links with the other PLANET modules

Table 57 and

Table 58 summarise the links of the Modal and Time Choice module with the other PLANET modules.

Table 57: Inputs in the Modal and Time Choice module of year *t* from the other PLANET modules

	Input from:	Year
Passenger trips for other purposes Transit tonnes lifted	Transport generation	*t*
O-D matrix Passenger transport: commuting and school (national and international trips) Freight transport: all goods types (national, from Belgium to ROW and vice versa)	Trip distribution	*t*
Average monetary costs, fuel costs and taxes per road mode	Vehicle stock	*t-1*

Table 58: Output of the Modal and Time Choice module of year *t* to the other PLANET modules

	Output to:	Year
Generalised cost of travelling between zone *i* and zone *k*, per trip motive/goods type	Trip distribution	*t+1*
- Total vehicle km of cars, LDV and HDV - Average time cost per car vkm for passenger transport	Vehicle stock	*t*
Average generalised cost of passenger transport for “other” purposes	Transport generation	*t+1*
Average generalised cost of transit freight in Belgium	Transport generation	*t+1*
- Number of commuting and school trips - Number of commuting trips by public transport - Number of passenger trips for “other“ purposes - Generalised cost per passenger trip (commuting, school, other) - Number of tonnes lifted per NST/R category (national, from Belgium to ROW, from ROW to Belgium, transit) - Generalised cost per tonne lifted per NST/R category (national, from Belgium to ROW, from ROW to Belgium, transit) - Cost to employer of commuting trip by public transport - Net tax revenue of commuting trips and other passenger trips - Net tax revenue from freight transport - Emissions of CO, CH4, NOx, PM, VOC, SO2, CO2 and N2O	Welfare	*t*

6. The Welfare Module

6.1. Introduction

The welfare module computes the welfare impact of the different policy scenarios. The welfare changes are calculated by comparing the policy scenarios with the business-as-usual scenario. The module proceeds in two steps. First, it calculates the welfare impact at a given point in time. The methodology is discussed in Section 6.2. Next, Section 6.3 discusses how the net present value of these welfare impacts is derived. Finally, Section 6.4 presents the links with the other PLANET modules.

6.2. Welfare at given point in time

The change in welfare at a given point in time is calculated as the sum of

- the change in consumer surplus;
- the change in producer surplus;
- the change in net tax revenue, multiplied by a correction factor;
- the change in environmental quality.

Each of these components is discussed in more detail below.

In addition to these impacts, we can also expect impacts of the policy scenarios on traffic safety and noise levels. However, these are not included in the welfare analysis. The reasons for this differ in the two cases. In the first case, calculating the social costs of accidents would require the incorporation of functions relating the accident risks of the different transport modes to their use, given a business-as-usual scenario for the policy measures in this domain. Indeed, it can be expected that the accident risks will change as the traffic level and its composition changes. The construction of such a function is not straightforward and we do not know of a Belgian study on which we can base ourselves. A possible approach could be to base ourselves on the current accident risks, but this would be a rough approximation only. For noise nuisance, given the aggregate nature of the model, we feel that it is unsuited to model the effects on noise nuisance, for which a much more spatially disaggregated model is required.

6.2.1. The change in consumer surplus

Figure 30 illustrates how the change in consumer surplus is calculated if the generalised costs are higher in the alternative scenario than in the business-as-usual (BAU) scenario. In the BAU scenario the number of trips and the generalised cost of these trips in year *t* are given by $x_{BAU,t}$ and $gc_{BAU,t}$ respectively. In the alternative scenario the new equilibrium is given by $x_{1,t}$ and $gc_{1,t}$.

The change in consumer surplus in year *t* can be calculated as follows:

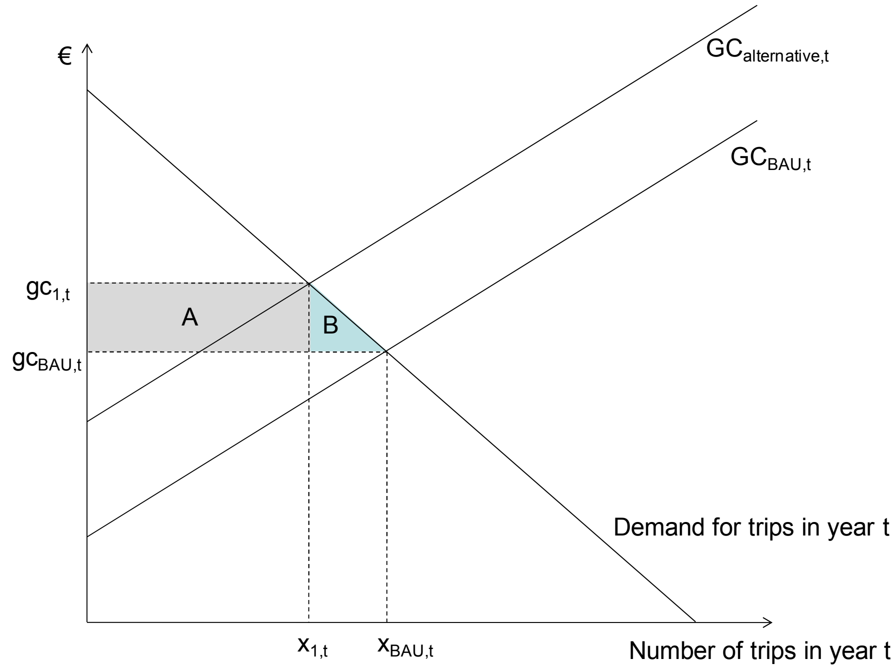
$$\Delta CS_t = -A - B = x_{1,t}\left(gc_{BAU,t} - gc_{1,t}\right) + \left(x_{BAU,t} - x_{1,t}\right)\left(gc_{BAU,t} - gc_{1,t}\right)/2$$

A positive value corresponds with a welfare increase.

In the case of commuting and school transport the number of trips is assumed to be the same in the alternative and BAU scenario ($x_{BAU}=x_1$). For these trips the second term in the expression for the change in consumer surplus therefore drops out.

It should be noted that the change in consumer surplus takes into account the impact of the policy scenarios on congestion. If the congestion level is changed, this is reflected into a change in the generalised costs.

Figure 30: The change in consumer surplus



6.2.2. Change in producer surplus

The change in producer surplus consists of two parts.

The first part is the change due to the changed transport costs for freight transport. This part of the change in producer surplus ($\Delta PS_{1,t}$) is calculated as follows:

$$\Delta PS_{1,t} = xf_{1,t}\left(gcf_{BAU,t} - gcf_{1,t}\right) + \left(xf_{BAU,t} - xf_{1,t}\right)\left(gcf_{BAU,t} - gcf_{1,t}\right)/2$$

$xf_{BAU,t}$ and $gcf_{BAU,t}$ stand for the number of tonnes lifted and the generalised cost per tonne lifted in year t of the BAU scenario. $xf_{1,t}$ and $gcf_{1,t}$ refer to the same variables in the alternative scenario. A positive value of $\Delta PS_{1,t}$ refers to a welfare increase.

For all transport flows except transit freight the number of tonnes lifted are assumed not to be influenced by policies. Therefore, the second term of $\Delta PS_{1,t}$ drops out in this case. For transit freight transport the model takes into account the impact of transport policies on transit tonnes transported through Belgium.

For national and transit freight transport the welfare calculation only considers the impacts on the transport costs related to transport in Belgium. For national transport the reason for this is evident. For transit transport this is done because the model does not explicitly consider the part of transit transport that takes place abroad. For freight transport from Belgium to the ROW and vice versa the welfare measure considers the impacts both in Belgium and abroad.

The change in producer surplus includes the impact of the policy scenarios on congestion. If the congestion level is changed, this is reflected into a change in the generalised costs.

The second part of the change in producer surplus ($\Delta PS_{2,t}$) refers to the change in the contribution of the employers to the commuting costs of their employees, when they travel by public transport. This contribution is calculated as the product of the number of commuting trips by public transport and the cost per trip for employers.

6.2.3. Change in net tax revenue

The third component of the change in welfare is the net change in tax revenue from the transport sector, multiplied by a correction factor. This correction factor is present because if no transport taxes are imposed, the government would need higher labour taxes or general taxes. The correction factor depends on the type of net transport tax revenue and on the tax instrument that is used to ensure budget neutrality.

It is well known that with distortionary taxes the social cost to raise 1 euro of additional government revenue is higher than 1 euro. In other words, the marginal cost of public funds (MCPF) of such taxes exceeds one. In general, the level of the MCPF increases with the initial tax rate and the elasticity of supply and demand. It falls with the size of the tax base. Kleven & Kleiner (2003) show that the MCPF of labour income taxation is high in Belgium if one takes into account both the decision to participate in the labour market and the decision on the number of hours worked (conditional upon working). For the labour income tax in Belgium they find a value larger than 2, implying that it costs more than 2 euro to raise 1 euro of additional tax revenue.

In our welfare calculations transport taxes imposed on commuters are taken to have the same efficiency costs as a labour tax. Other transport taxes are assumed to have the same efficiency cost as general taxes. This has the following implications for the correction factor that is applied to net changes in transport tax revenue. If the increase in the transport tax revenue is compensated by a reduction in a tax with the same efficiency cost, the correction factor is equal to unity. If the increase in the transport tax revenue is compensated by decreasing a tax with a higher efficiency cost, the correction factor is larger than unity (and vice versa). The calculation of the correction factors is given in

Table 59. In the welfare calculations we use the following values: $MCPF_{LIT} = 2.50$ and $MCPF_{GT} = 1.1$[63], based on Kleven and Kreiner (2003).

Table 59: Correction factors for net change in transport tax revenue

Type of additional tax revenue	Revenue recycling instrument	Correction factor
Transport taxes on commuting	Labour income tax*	= 1
	General taxes*	= $1/(MCPF_{LIT}\text{-}MCPF_{GT})$ (< 1)
Other transport taxes	Labour income tax	= $MCPF_{LIT}\text{-}MCPF_{GT}$ (> 1)
	General taxes	= 1

* LIT = labour income tax, GT = general tax

6.2.4. Change in environmental costs

The change in environmental costs (ΔEC) is calculated as follows:

$$\Delta EC = \sum_{poll} RED_{poll} DAM_{poll}$$

The model considers the following pollutants (indexed by *poll*): carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2). Furthermore, we consider three greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). RED_{poll} stands for the reduction in the emission of pollutant *poll* w.r.t. the BAU scenario (in tonnes). DAM_{poll} is the damage in euro per tonne of emissions of pollutant *poll*.

For the damage per tonne of emissions of NO_x, PM, VOC and SO_2 we base ourselves on the HEATCO project (Bickel et al., 2006). This project uses the impact-pathway method to estimate the damage of emissions. The impact-pathway method proceeds in four steps. Step 1 calculates the change in ambient concentrations of primary and secondary pollutants caused by an increase in emissions. Step 2 determines the population exposed to these concentrations. In Step 3 the impacts of the change in the ambient concentration are calculated. These impacts consist of impacts on mortality, morbidity and crops and of material damage. Finally, in Step 4 these damages are valued in monetary terms. The damage per tonne of CO emissions is based on Friedrich and Bickel (2001) who use a similar methodology[64]. The damage per tonne of air pollution is assumed to change proportionally with real GDP per capita, following the guidelines of the HEATCO project.

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[63] Both values refer to the case where the uncompensated hours-of-work elasticity equals zero and the participation elasticity equals 0.2. The value of $MCPF_{LIT}$ refers to the MCPF of a proportional reform taking into account out-of-work benefits, as reported in Table II of Kleven & Kreiner (2003). The value of $MCPF_{GT}$ refers to a reform of average taxes, as reported in the same table.

[64] For more details on the damage estimation the reader is referred to Bickel et al. (2006) and Friedrich and Bickel (2001).

Table 60: Average damage per tonne of emission in Belgium (euro2000/tonne)

Emission	NO_x	CO		NMVOC	SO_2	$PM_{2.5}$	
Concentration	O3, nitrates, NOx	CO		O3	Sulphates, acid deposition, SO_2	Primary PM2.5	
		Urban	Non-urban			Urban	Non-urban
Transport	2605	3.15	0.83	1061	5211	424578	91670
High source	2605			1061	5500	16404	13509

Source: Bickel et al. (2006) for all pollutants except CO; Friedrich and Bickel (2001) for CO

Since the damage of $PM_{2.5}$ and CO depends on the location where the pollutants are emitted, we need information on the share of vkm driven in urban and non-urban areas. This is summarised in Table 61. For road transport (except bus, tram, metro) the shares are based on FOD Mobiliteit en Transport/SPF Mobilité et Transports (2001). For the other modes they are based on own assumptions.

Table 61: The share of vkm driven in urban areas

	Share of vkm in urban areas		Share of vkm in urban areas
Car	30%	Road LDV	30%
Motorcycle	30%	IWW	0%
Bus, tram, metro	50%	Passenger trains (diesel)	10%
Road HDV	10%	Freight trains (diesel)	0%

The damage per tonne of emissions of SO_2 and $PM_{2.5}$ is also lower for emissions by high sources than by transport vehicles. Therefore, in order to calculate the damage of emissions by rail, we need information on the share of electric and diesel trains. Data from the NMBS/SNCB show that in the case of freight rail the share of electric trains in gross tkm increased from 73% to 78% between 2000 and 2005. We assume that it remains constant afterwards. In the case of passenger rail the share of electric rail in gross tkm is taken to be 96%, based on the same source.

The monetary valuation of the damages caused by CO_2, CH_4 and N_2O is based on Watkiss et al. (2005)(as reported in Bickel et al., 2006). The damage per tonne of CO_2 equivalent[65] is presented in Table 62. The values reflect the finding of recent studies that future emissions will cause a larger damage than present emissions. The values proposed by Watkiss et al. (2005b) are shadow price values, which take into account the expected future development of damage costs and abatement costs. It should be noted that the abatement costs are based on assumptions for the UK, namely on the UK government's long-term goal of meeting a 60% CO_2 reduction by 2050 (which is broadly consistent with the EU's 2°C target). However, they only influence the cost curve starting from about 2030, the final year considered in the PLANET model. Therefore, the figures can be used in our framework. The monetary cost per tonne of CO_2 can also be considered to be somewhat conservative since the damage cost estimates do not include some important risks. An interesting aspect of the Watkiss et al. (2005)

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[65] The global warming potential of N_2O and CH_4 are 310 and 21, respectively.

study is that it presents not only a central value, but also a low and a high value. This way we can perform a sensitivity analysis of the welfare calculations w.r.t. the monetary cost of CO_2 emissions.

Table 62: The monetary cost per tonne of CO_2 equivalent emissions (euro2000/tonne)

	2000-2009	2010-2019	2020-2029	2030
Low	14	15	19	25
Central	21	25	31	39
High	49	61	78	99

Source: Watkiss et al. (2005) as reported in Bickel et al. (2006)

6.3. The net present value of changes in welfare

The net present value of the changes in welfare is calculated with 2000 as the base year and using a discount rate of 4%. It is given by:

$$NPV = \sum_{n=0}^{30} \frac{B_n}{(1+i)^n}$$

B_n is the net benefit realised in year n, expressed in euro of 2000. i is the real social discount rate.

6.4. The links with the other PLANET modules

The links with the other modules are summarised in Table 63.

Table 63 : Inputs in the welfare module of period *t*

	Input from:	Year
- Number of commuting and school trips - Number of commuting trips by public transport - Number of passenger trips for “other“ purposes - Generalised cost per passenger trip (commuting, school, other) - Number of tonnes lifted per NST/R category (national, from Belgium to ROW, from ROW to Belgium, transit) - Generalised cost per tonne lifted per NST/R category (national, from Belgium to ROW, from ROW to Belgium, transit) - Cost to employer of commuting trip by public transport - Net tax revenue of commuting and other passenger trips - Net tax revenue from freight transport - Emissions of CO, CH_4, NO_x, PM, VOC, SO_2, CO_2 and N_2O	Modal and time choice[1]	*t*

[1] For the BAU scenario and alternative scenarios

7. Annex

7.1. The NST/R chapters

Table A 1: The NST/R chapters

NST/R chapter	Description
0	Agricultural Products and Live Animals
1	Foodstuffs and animal fodder
2	Solid mineral fuels
3	Petroleum products
4	Ores and metal waste
5	Metal products
6	Crude and manufactured minerals, building materials
7	Fertilizers
8	Chemicals
9	Machinery, transport equipment, manufactures articles and miscellaneous articles

7.2. Correspondence between SUT branches and HERMES branches

Table A 2: Correspondence between SUT branches and HERMES branches

SUT	HERMES	SUT	HERMES	SUT	HERMES	SUT	HERMES
01A	A	24D	Q	36B	C	70A	OS
02A	A	24E	Q	36C	C	71A	OS
05A	A	24F	Q	37A	C	71B	OS
14A	Q	24G	Q	40A	E	72A	OS
15A	C	25A	C	41A	E	73A	OS
15B	C	25B	C	45A	B	74A	OS
15C	C	26A	Q	45B	B	74B	OS
15D	C	26B	Q	45C	B	74C	OS
15E	C	26C	Q	45D	B	74D	OS
15F	C	26D	Q	45E	B	74E	OS
15G	C	27A	Q	50A	HA	74F	OS
15H	C	27B	Q	50B	HA	75A	N
15I	C	28A	Q	51A	HA	75B	N
15J	C	28B	Q	52A	HA	75C	N
15K	C	28C	Q	55A	HA	80A	N
15L	C	29A	K	55B	HA	85A	SA
16A	C	29B	K	60A	Z	85B	SA
17A	C	29C	K	60B	Z	85C	SA
17B	C	29D	K	60C	Z	90A	OS
18A	C	30A	K	61A	Z	91A	OS
19A	C	31A	K	61B	Z	92A	OS
20A	C	31B	K	62A	Z	92B	OS
21A	C	32A	K	63A	Z	92C	OS
22A	C	33A	K	63B	Z	92D	OS
22B	C	34A	K	64A	Z	93A	OS
23A	E	34B	K	64B	Z	95A	N
24A	Q	35A	K	65A	CR		
24B	Q	35B	K	66A	CR		
24C	Q	36A	C	67A	CR		

Legend: the HERMES branches:

A Agriculture
E Energy
Q Intermediate goods
K Equipment goods
C Consumer goods
B Construction

HA Trade and catering
Z Transport and communication
CR Credit and insurance
SA Health care
OS Other market services
N Non-market services

7.3. Correspondence between SUT products and NST/R chapters

Table A 3: Correspondence between SUT products and NST/R chapters

SUT	NST/R	SUT	NST/R	SUT	NST/R	SUT	NST/R	SUT	NST/R
01A01	0	15K01	1	24A02	8	28A03	9	36B02	9
01A02	0	15K02	1	24A04	8	28A04	9	36C01	9
01A03	0	15K03	1	24B01	8	28A05	5	36C02	9
01A04	0	15K04	1	24C01	8	28B01	5	36C03	9
01A05	1	15L01	1	24D01	8	28C01	9	37A01	4
01A06	0	16A01	1	24D02	8	28C02	9		
01A07	0	16A02	0	24D03	8	28C03	9		
01A08	1	17A01	0	24E01	8	29A01	9		
01A09	0	17A02	9	24E02	8	29A02	9		
01A10	0	17A03	9	24F01	8	29B01	9		
02A01	0	17B01	9	24F02	8	29B02	9		
05A01	1	17B02	9	24F03	8	29B03	9		
10A01	2	17B03	9	24F04	8	29C01	9		
11A01	3	17B04	9	24F05	8	29C02	9		
12A01	4	17B05	9	24G01	9	29C03	9		
13A01	4	18A01	9	25A01	9	29C04	9		
14A01	6	18A02	9	25A02	9	29C05	9		
14A02	6	18A03	9	25B01	9	29C06	9		
14A03	6	19A01	9	25B02	9	29C07	9		
15A01	1	19A02	9	25B03	9	29C08	9		
15A02	1	19A03	9	25B04	9	29D01	9		
15A03	1	20A01	0	26A01	9	30A01	9		
15A04	1	20A02	9	26A02	9	30A02	9		
15A05	1	20A03	9	26A03	9	31A01	9		
15A06	1	20A04	9	26A04	9	31A02	9		
15B01	1	20A05	9	26A05	9	31B01	9		
15C01	0	21A01	9	26B01	9	31B02	9		
15C02	1	21A02	9	26B02	6	31B03	9		
15C03	1	21A03	9	26B03	6	32A01	9		
15D01	1	21A04	9	26C01	6	32A02	9		
15D02	1	21A05	9	26C02	6	32A03	9		
15E01	1	21A06	9	26D01	6	33A01	9		
15E02	1	22A01	9	26D02	6	33A02	9		
15E03	1	22A02	9	26D03	6	33A03	9		
15E04	1	22A03	9	26D04	6	33A04	9		
15F01	1	22A04	9	26D05	6	34A01	9		
15F02	8	22B01	9	27A01	5	34A02	9		
15G01	1	22B02	9	27A02	5	34A03	9		
15G02	1	22B03	9	27A03	5	34A04	9		
15H01	1	22B04	9	27A04	5	34A05	9		
15H02	1	23A01	2	27B01	5	34B01	9		
15I01	1	23A05	3	27B02	5	34B02	9		
15I02	1	23A06	3	27B03	5	35A01	9		
15I03	1	23A07	3	27B04	5	35A02	9		
15I04	1	23A08	8	27B05	5	35A03	9		
15J01	1	23A02	3	27B06	5	35B01	9		
15J02	1	23A03	3	27B07	5	36A01	9		
15J03	1	23A04	3	28A01	9	36A02	9		
15J04	1	24A01	8	28A02	9	36B01	9		

7.4. Correspondence and elasticities between NST/R and HERMES products

Table A 4: Correspondence and elasticities between NST/R and HERMES products

NST/R	HERMES		Elasticity	
	Imports	Exports	Imports	Exports
0	0.74*A + 0.26*C	0.65*A + 0.35*C	0.8	0.9
1	0.97*C + 0.03*A	0.99*C + 0.01*A	0.9	1.0
2	E1 + E2	E1 + E2	1.0	1.0
3	E3 + E4	E3 + E4	1.0	1.0
4	Q	Q	0.9	1.0
5	Q	Q	0.8	0.7
6D	Q	Q	1.0	1.0
6Z	Q	Q	0.5	0.8
7	Q	Q	0.3	0.1
8	0.99*Q + 0.01*C	0.99*Q + 0.01*C	1.25	1.35
9	0.64*K + 0.29*C + 0.07*Q	0.61*K + 0.32*C + 0.07*Q	1.1	1.1

Legend:
HERMES products
A Agricultural products
E1 + E2 Coal and cokes
E3 + E4 Crude oil and petroleum products
Q Intermediate goods
K Equipment goods
C Consumer goods
p.m. NST/R6
6D Precious stones
6Z Other minerals and building material
p.m. NST/R7

No SUT product could be isolated (NST/R7 is a minor part of SUT product 24A03); for this reason a fictitious product has been created, corresponding to the import (resp. export) value of NST/R7 based on CN-8 data.

7.5. The Poisson model

The estimation of the doubly constrained gravity model with barrier effect (presented in Section 4.2.1.a) by the Poisson model proceeds as follows. In the Poisson model the probability that J_{ik} corresponds with the number of journeys between *i* and *k* is given by:

$$P(J_{ik}) = \left[\exp(-\lambda_{ik})\lambda_{ik}{}^{J_{ik}}\right] / J_{ik}!\,.$$

where $J_{ik}!$ is the factorial of J_{ik}. The loglikelihood of a series of observed flows where each flow is the result of a particular Poisson process, is:

$$L^* = \sum_{i,k} \ln\left[\exp(-\lambda_{ik})\lambda_{ik}{}^{J_{ik}}\right] / J_{ik}!\,.$$

Maximising this function boils down to maximising:

$$Z = \sum_{i,k} \left(J_{ik} \ln \lambda_{ik} - \lambda_{ik}\right).$$

This function must be maximised w.r.t. d_i, h_k, β_0 and β_1. The following system of equations ensures the maximisation of *Z*:

$$\sum_k J_{ik} = \sum_k \lambda_{ik} \qquad \forall i$$

$$\sum_i J_{ik} = \sum_i \lambda_{ik} \qquad \forall k$$

$$\sum_{i,k} T_{ik}(1 - B_{ik})\ln c_{ik} = \sum_{i,k} \lambda_{ik}(1 - B_{ik})\ln c_{ik}$$

$$\sum_{i,k} J_{ik} B_{ik} \ln c_{ik} = \sum_{i,k} \lambda_{ik} B_{ik} \ln c_{ij}$$

The first series of first order conditions ensures that $P_i = \sum_k \lambda_{ik}$ ($\forall i$). The second series ensures that $D_k = \sum_i \lambda_{ik}$ ($\forall k$).

7.6. The transport modes of the socio-economic survey of 2001

Table A 5 gives an overview of the transport modes that are considered in the socio-economic survey of 2001. The last column summarises how the SES2001 are assigned to six main modes.

Table A 5: The transport modes considered in the socio-economic survey of 2001

Code	Description	Main mode
1	Foot	Slow
2	Bicycle	Slow
3	Motorcycle, moped	Moto
4	Motorcycle, moped + Bicycle	Moto
5	Transport organised by employer or school	Bus,tram,metro
6	Transport organised by employer or school l + Bicycle	Bus, tram,metro
7	Transport organised by employer or school + Motorcycle, moped	Bus, tram,metro
8	Car (driver)	Car driver
9	Car (driver) + Bicycle	Car driver
10	Car (driver) + Motorcycle, moped	Car driver
11	Car (driver) + Transport organised by employer or school	Bus, tram,metro
12	Car (passenger)	Car passenger
13	Car (passenger) + Bicycle	Car passenger
14	Car (passenger) + Motorcycle, moped	Car passenger
15	Car (passenger) + Transport organised by employer or school	Bus, tram,metro
16	Car (passenger) + Car (driver)	Car passenger
17	Train	Train
18	Train + Bicycle	Train
19	Train + Motorcycle, moped	Train
20	Train + Transport organised by employer or school	Train
21	Train + Car (driver)	Train
22	Train + Car (passenger)	Train
23	Bus, tram, metro	Bus, tram, metro
24	Bus, tram, metro + Bicycle	Bus, tram, metro
25	Bus, tram, metro + Motorcycle, moped	Bus, tram, metro
26	Bus, tram, metro + Transport organised by employer or school	Bus, tram, metro
27	Bus, tram, metro + Car (driver)	Car driver
28	Bus, tram, metro + Car (passenger)	Car passenger
29	Bus, tram, metro + Train	Train

7.7. Estimations of the school trip distributions

Table A 6: Comparison of school trip distribution models with fixed and variable barrier effects

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Ln(GC*) intra-zonal	-3.50	-19.0	-3.44	-32.45	-3.43	-32.35	-3.436	-32.45
Ln(GC) intra-regional (Def. 1 & 3)	-3.69	-35.08			-3.66	-60.40		
Ln(GC) intra-regional (Def. 2)			-3.67	-60.85			-3.67	-60.85
Ln(GC) inter-regional (Def. 1)	-3.38	-23.96						
Ln(GC) inter-regional (Def. 2)			-3.58	-12.59			-3.62	-5.54
Ln(GC) inter-regional 1 (Def. 3)					-3.58	-12.59		
Ln(GC) inter-regional 2 (Def. 3)					-3.70	-57.66		
GC inter-regional (Def. 2)							0.00	0.058
Dummy barrier inter-regional (Def. 1)	-2.17	-5.68						
Dummy barrier inter-regional (Def. 2)			-2.67	-4.41			-2.62	-2.57
Dummy barrier inter-regional 1 (Def. 3)					-2.67	-4.40		
Production dummy – Antwerp	13.42	36.72	13.30	58.28	13.30	58.24	13.30	58.27
Production dummy – Brussels	11.77	30.59	12.85	57.63	12.79	56.26	12.85	57.62
Production dummies – other zones**	…	…	…	…	…	…	…	…
Attraction dummy – Antwerp	2.49	9.14	2.52	13.44	2.52	13.45	2.52	13.44
Attraction dummy – Brussels	4.78	17.67	3.57	20.66	3.62	20.39	3.57	20.66
Attraction dummy – other zones**	…	…	…	…	…	…	…	…
Log-likelihood	-30334.40		-23500.77		-23468.49		-23500.72	

* GC = weighted generalised cost

** Results not reported but available upon request

Table A 7: Comparison of school trip distribution models with different types of barrier effect

	Model 2		Model 5		Model 6	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Ln(GC*) intra-zonal	-3.44	-32.45			-3.37	-30.62
Ln(GC) intra-regional (Def. 2)	-3.67	-60.85			-3.63	-58.07
Ln(GC) inter-regional (Def. 2)	-3.58	-12.59			-4.85	-54.64
Ln(GC)			-3.94	-167.25		
Dummy barrier inter-regional (Def. 2)	-2.67	-4.41	-2.58	-24.48		
Production dummy – Antwerp	13.30	58.28	0.87	4.74	13.2	55.11
Production dummy – Brussels	12.85	57.63	0.47	2.83	12.77	54.51
Production dummies – other zones**	…	…	…	…	…	…
Attraction dummy – Antwerp	2.52	13.44	15.66	82.90	2.49	12.59
Attraction dummy – Brussels	3.57	20.66	16.71	95.46	3.54	19.44
Attraction dummy – other zones**	…	…	…	…	…	…
Log-likelihood	-23500.77		-23877.96		-23743.47	

* GC = weighted generalised cost

** Results not reported but available upon request

7.8. Deriving the origin-destination matrix from a production-attraction matrix

The transformation of a production-attraction matrix into an origin-destination matrix is illustrated for a production-attraction matrix with 2 zones that looks as follows:

Table A 8: A production-attraction matrix for two zones

		Attraction		
		1	2	Total
Production	1	J_{11}	J_{12}	P_1
	2	J_{21}	J_{22}	P_2
	Total	A_1	A_2	$\sum_{i,k} J_{ik}$

The origin-destination matrix is constructed as follows:

Table A 9: Deriving the origin-destination matrix from a production-attraction matrix (2 zones)

		Destination		
		1	2	Total
Origin	1	$T_{11} = 2*J_{11}$	$T_{12} = J_{12}+J_{21}$	$O_1 = T_{11}+T_{12}$
	2	$T_{21} = J_{21}+J_{12}$	$T_{22} = 2* J_{22}$	$O_2 = T_{21}+T_{22}$
	Total	$D_1 = T_{11}+T_{21}$	$D_2 = T_{12}+T_{22}$	$2* \sum_{ik} J_{ik}$

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