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SCIENCE FOR A SUSTAINABLE DEVELOPMENT

LONG-RUN IMPACTS OF POLICY PACKAGES ON MOBILITY IN BELGIUM

"LIMOBEL"

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SCIENCE FOR A SUSTAINABLE DEVELOPMENT
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Transport and Mobility

FINAL REPORT PHASE 1

LONG-RUN IMPACTS OF POLICY PACKAGES ON MOBILITY IN BELGIUM

"LIMOBEL"

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List of abbreviations

cc	Cylinder capacity
CES	Constant elasticity of substitution
CGE	Computable general equilibrium
CNG	Compressed Natural Gas
CRIA	Constant relative inequality aversion
DCW	Digital chart of the world
DIV	Directie inschrijvingen voertuigen/Direction pour l'immatriculation des véhicules
E-motion	Energy- and emission MOdel for Transport with geographical distributION
GAMS	General Algebraic Modeling System
GDP	Gross domestic product
H2	Hydrogen gas
HDVa	Heavy Duty Vehicles articulated
HDVr	Heavy Duty Vehicles rigid
HFC-134a	tetrafluoroethane
ICE	Internal Combution Engine
LPG	Liquefied Petroleum Gas
MAC	Mobile air-conditioning
NBB	National Bank of Belgium
NEG	New economic geography
NST/R	Classification of goods for freight transport
O-D matrix	Origin-destination matrix
PHEV	Plug-in Hybrid Electric Vehicle
R&D	Research and development
RVA	Rijksdienst voor arbeidsvoorziening/Office national de l'emploi (ONEM)
SILC	Statistics on income and living condition
SLQ	Single location quotient
t	Tonne
tonne-km	tonne-kilometre
vkm	Vehicle kilometre

1. Introduction

1.1. Context

LIMOBEL deals with three priority research areas that are interrelated: transport and mobility, energy and environmental issues. It is well known that, while generating many benefits, transport also causes many problems, of which congestion, accidents and environmental costs are the most important. Both at the Belgian (regional and federal) level and the European level authorities consider different types of government intervention in order to bring about a more sustainable transport system. LIMOBEL can form a basis for the formulation of policies because:

- it analyses the interaction between mobility and environmental problems, by explicitly considering the environmental costs of transport and by considering the impact of policy measures on the different transport related problems (congestion, accidents, environmental problems, energy use) and by not concentrating on only one problem.
- it considers policy packages, consisting of different instruments (pricing, regulation, infrastructure measures) that may address different transport problems. It analyses complementarities and synergies between these instruments. Besides transport instruments, the packages will also contain more general instruments (non-transport taxes, transfers) to ensure budget neutrality.
- it considers a time horizon up to 2030 and therefore produces a long term view of sustainable mobility and the mobility policies necessary to reach it. This time horizon also makes the project relevant for the negotiations about greenhouse emissions beyond the Kyoto protocol.

It considers the economic evolution at the regional level and incorporates a network model. Therefore, the project explicitly takes into account the spatial dimension.

1.2. Objectives and expected outcomes

The aim of LIMOBEL is to develop a fully operational modelling tool to study the impact of transport policies on the economy and on emissions in order to help the government make choices when it is faced with different objectives. The project will produce long-term projections (up to 2030) of passenger and freight transport demand in Belgium. A baseline scenario will be constructed which will be compared with alternative policy scenarios for more sustainable transport. In the alternative policy scenarios, packages of instruments will be considered, including pricing instruments, regulation and infrastructure measures. The pricing and regulation instruments can concern both the use and the ownership of vehicles. Besides transport instruments the project may also consider more general instruments (such as labour taxes, transfers) in order to ensure budget neutrality.

The first output of LIMOBEL consists of a baseline scenario for Belgium with a time horizon of up to 2030. It will provide projections of the economic activity in Belgium and on transport demand. The transport related output will consist, amongst others, of the following aspects:

- the number of trips per trip purpose and consumer type (for passenger transport), the tonnes transported per goods type (for freight transport), the origin and destination of the transport flows, the modal choice and the time of day (peak and off-peak), the route choice and the vehicle technology;

- energy use by transport;
- the transport emissions;
- the net transport tax revenue for the federal and regional governments;
- the marginal external costs of transport.

Secondly, LIMOBEL will perform a cost-benefit analysis of several budget-neutral policy packages. The modelling tool computes the impact of these policies on economic performance, transport demand, energy use, emissions, congestion, accidents and welfare (in general and of the different economic agents). As such the modelling tool allows us to study the trade-offs which often have to be made between different government objectives.

2. Methodology and results

The structure of this section is based on the division of the work into workpackages and tasks, as described in the technical specifications of the contract.

2.1. Workpackage 1: Coordination

Task 1.1: Connecting the different tasks

The three LIMOBEL model components

The project basically uses three models

- PLANET2: the model for long-term transport projections, which includes a long-term economic model (PLANET2 extends PLANET1 by integrating the two-way interactions between the economy and transport);
- NODUS: the network model for passenger and freight transport;
- E-motion: the environmental impact assessment model.

The three models are linked to each other, but do not optimise simultaneously. Even if different models are used in LIMOBEL, with various inputs and outputs between each other, the whole LIMOBEL model is not an iterative process between these models.

The three modelling approaches are necessary given the aims of the LIMOBEL project. Moreover, given the aims of LIMOBEL a certain level of detail is required.

Long-term economic model

The long term economic model should be capable to indicate likely magnitudes of policy induced changes from future baselines, and to rank alternative policy measures. In order to illustrate the mechanisms through which policies work, a simple model would suffice. However, when one is interested in the impacts at the regional, sectoral level and for different household types a more elaborate model is required. In the interpretation of the results the team can build upon previous experience with this type of models and on its knowledge of economic theory.

CGE models belong to a class of macroeconomic models which has the application of an Arrow-Debreu general equilibrium framework as its theoretical basis. The commonly made assumption is that all agents optimise their behaviour. The impacts of policy simulations are therefore not generated from a black box but can be traced back to rational behaviour.

Network model

The aim of the network model is to analyse the impact of pricing and infrastructure policies on the transport flows on the networks, transport costs, modal split and speed. This requires a detailed network model with an interaction between freight and passenger transport. This network model must also be fed by detailed origin-destination matrices for both types of trips.

<u>Environmental impact assessment model</u>

The environmental impact assessment tool consists of an emission model for road, railway and shipping traffic on the one hand and an external environmental cost model on the other hand. The main aim of this tool within the LIMOBEL project is to provide the CGE model with the latest know-how on fuel efficiency, emission factors and damage per tonne of emissions.

The emission model is basically a technological model that contains new evolutions in conventional vehicle technology, as well as alternative fuels and motor vehicle technologies which could be coming up within a time horizon up to 2030.

The external environmental cost model is based on the work done within the series of European projects commonly known as ExternE. The ExternE model has proposed both exposure-response functions and economic values for all known impacts. The major external costs of transport emissions are global warming effects on one hand and public health impacts on the other. The latest updates for these major categories have been taken from the recently finished NEEDS project.

The links between the three model components

An overview was made by the three teams of the most important links between the three model components of LIMOBEL. The results of the discussion are summarised in a note that is included as an annex to this report (Annex 1A). Here we restrict ourselves to the main conclusions that were drawn from the exercise. We refer the reader to the accompanying note for a more detailed discussion of the connection between the three models.

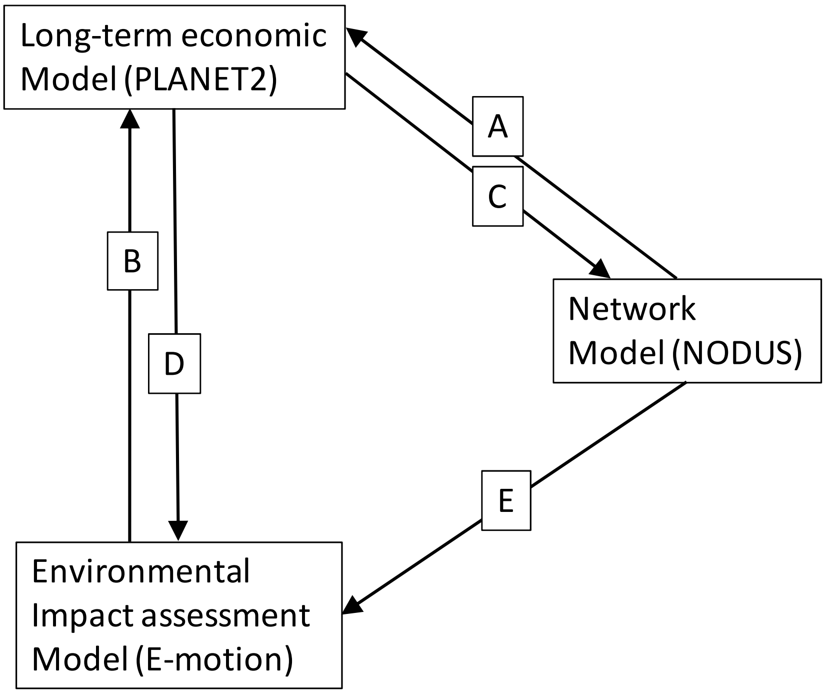
Figure 1 and Table 1 present a short overview of the main links that have been identified between the three model components. The letters in the first column of Table 1 correspond with the names of the links used in Figure 1.

In addition, other aspects for coordination were determined. These refer to, amongst others, the historical fleet information for all vehicles (including company cars as a separate category), the exogenous evolution of the vehicle stock for vehicles other than cars, the monetary costs of transport by rail, inland navigation and bus/tram/metro, the share of different road types for road transport, etc.

Task 1.2 to 1.4: Organisation and dissemination, follow-up committee and reporting

In the first two years of the project these tasks mainly involved ensuring good communication with the PPS Science Policy, the organisation of meetings with the follow-up committee and the publication of the intermediary and evaluation reports. These tasks proceeded as planned.

Figure 1: The links between the LIMOBEL model components



2.2. Workpackage 2: Long Term Economic Modelling

Task 2.1: Literature review

A literature review was made as a basis for the long-term economic modelling. Since the aims at this stage of the project were very similar to those of the ISEEM project, the review was made in close collaboration with that project in which the FPB also participates. The result is a joint report for the ISEEM and LIMOBEL projects that is included as an annex to this report (Annex 1B).

A selection of applied and theoretical models were analysed in a detailed way. The applied models can be categorised into four categories: conventional computable general equilibrium (CGE) models, CGE models that are based on new economic geography theory (NEG CGE model), transport-land use interaction models and macro-economic models. An overview of the reviewed applied models is given in Table 2.

It turns out that conventional CGE models and NEG CGE models are the most relevant given the LIMOBEL aims, though the other types of models can also provide inputs. Both conventional and NEG CGE models are able to consider different regions. NEG models are able to capture agglomeration effects – and are therefore especially suited to calculate the spatial impacts of large infrastructure projects. However, NEG models are still more experimental.

Table 1: The links between the LIMOBEL model components

A	**Input from the network model in the long-term economic model** a) Elements to compute generalised transport costs - Average distance per zone-pair - Average transport time per zone pair - Components of transport time b) Share of the different road types Notes: - Aggregation to level of detail of PLANET2 (NUTS3 zones = 'arrondissementen/arrondissements') - Input with a lag of one year - This information is not available for trips that stay within a municipality
B	**Input from the environmental impact assessment model in the long-term economic model** - Emission factors of different vehicle types (by road type) - Fuel efficiency of different vehicle types (by road type) - Damage per tonne of emissions, according to NUTS3 zone and road type
C	**Input from the long-term economic model in the network model** - Future origin-destination matrices freight - Future origin-destination matrices school and commuting - Future origin-destination matrices business & other (subject to data availability) - Monetary costs car, vans, trucks - Wage cost, value of time Notes: - Transformation required to level of detail of NODUS - Input with a lag of one year
D	**Input from the long-term economic model in the environmental impact assessment model:** - Composition of the car stock and its evolution - Age structure of the vehicle stock for buses, vans, trucks - Gross domestic product per capita
E	**Input from the network model in the environmental impact assessment model:** - Share of different weight classes for inland navigation

Table 2: Overview of reviewed applied models for the long-term economic model

Type of model	Models reviewed	Main source
Conventional CGE	GEM – E3 (with regional version for Belgium) EPPA GreenModII Mayeres (1999) MMRF – Green EDIP	Capros e.a. (1997) Saveyn & Van Regemorter (2006) Paltsev e.a. (2005) Bayar (2006) Mayeres (1999) Adams e.a. (2002) T.M.Leuven
NEG CGE	CGEurope I and II RAEM 2.0 and 3.0 REMI	Bröcker e.a. (2001), (2004) Thissen (2002), Ivanova (2007) Treyz e.a. (2002)
Transport – land use interaction	RUBMRIO RELU	Ruiz Juri and Kockelman (2003) Safirova e.a. (2006)
Macro – economic	NEMESIS MOBILEC	NEMESIS (1999) Van de Vooren (2002)

Note: the full bibliographical references are given in the literature review that is included in Annex 1B.

Since LIMOBEL focuses on long-term economic modelling, the review first focused on modelling various aspects at a particular point in time. Next, we considered the way in which CGE models treat dynamics.

The review of the theoretical models covered the following topics: land use, endogenous growth and technological change, location decisions of households and firms, the labour market, ecological-economic models and stochastic elements in general equilibrium models.

Task 2.2.: Modelling

On the basis of the literature review a plan was constructed for the long-term economic model that is integrated in PLANET2. This plan was presented to the members of the scientific committee and modified, taking into account their comments. On this basis the modelling work has started (Task 2.2.1). In addition, we undertook a data collection exercise (Task 2.2.2). Both are described in more detail in the next paragraphs.

Task 2.2.1: Model construction and link with WP3 and WP4

Here we describe the main features of the model that is currently being constructed, based on the lessons drawn from the literature review and on the discussion with the follow-up committee. After consultation of the follow-up committee and the evaluation committee it was decided to change the original model set-up design in one respect. More particularly, the model will not consider capital vintages. The primary reason is that the necessary data are difficult to find. The discussion with the evaluation committee confirmed the importance of introducing imperfect competition. This can take the form of monopolistic competition (many firms selling different varieties of the same good) or oligopolistic competition (a small number of firms producing a certain good). The type of imperfect competition will depend on the sector that is considered.

The model is constructed in the GAMS language. It will be solved using the PATH solver.

Modelling the behaviour of economic agents at a given point in time

- *Consumer behaviour*

The CGE model considers different consumer groups (per region), characterised each by a utility function, a budget constraint and a time budget constraint. The inclusion of several consumer groups allows for an analysis of the distributional impacts of policies. The choice between consumption of different goods (including transport goods) is modelled by means of nested modified constant elasticity of substitution (CES) utility functions. Leisure demand is determined endogenously. For transport a distinction is made between three purposes (commuting, school and other purposes), different transport modes and period of travel (peak and off-peak). The model explicitly considers the link between the consumption of durables (such as cars) and non-durables (such as fuel). Since the literature review did not give us guidance on how to introduce company cars in the model, it is still investigated how this can be done. For this we are also following up the PROMOCO project.

Based on the Belgian Household Budget Survey, a number of representative household groups are selected. The term *representative* means that the set of households belonging to the same group behaves similarly in terms of their consumption patterns (with a highlight on the consumption of transport). Four relevant criteria are available from the national Household Budget Survey: the highest education level of the members of the households, total income of the household, household composition and place of residence (urban, semi-urban, rural).

Household income, household composition and the place of residence are three criteria often considered as relevant in order to take the heterogeneity of the consumers in terms of mobility into account. These three criteria will consequently be favoured in the selection of the representative household groups (possibly using educational level as a proxy for income, since these two are highly correlated). The estimation of the consumer behaviour model will not be able to take into account the region of the household, since the Household Budget Survey is not representative by region. However, the model will take into account the different shares of the household groups in the three regions.

- *Producer behaviour*

The model considers 24 sectors (per region), 7 of which are transport sectors. The production functions are of the nested CES type, with the following inputs: capital, two types of labour and a number of intermediate inputs (including freight and business transport, by different modes and with a distinction between peak and off-peak transport). A link is made between the input of durable and non-durable inputs. As regards the introduction of company cars, the same remark holds as for the consumer behaviour.

For a number of sectors we assume that perfect competition holds. For the other sectors we assume imperfect competition. In these sectors the cost structure of each firm consists of variable and fixed costs. Firms in these sectors set mark-ups on marginal costs. The price/cost margins generally depend on the type of oligopolistic regime, the relative market shares and the competitive environment. In the Cournot model a firm operates under the assumption that its rivals will not change their supply as a result of a change in the firm's supply.

The equilibrium number of firms is determined by the assumption of free entry/exit which leads to zero profits. The number of firms is therefore endogenous.

Rail transport and other public transport are specific sectors, characterized by increasing returns to scale but in which the entry of new firms is either not allowed or very limited. These sectors are also characterized by a high extent of government intervention.

The introduction of imperfect competition has implications for the modelling of demand by firms, consumers and the government. The model integrates "love of variety"; all consumers may benefit from the expansion of varieties and can achieve efficiency gains in the volume and costs of their consumption.

- *The labour market*

The labour market makes a distinction between two skill types (low and high skilled). Each region has an endogenous labour supply.

The most realistic way to model frictional unemployment in Belgium is through wage bargaining between employers and unions at the sectoral level (nationally). Commuting between regions is being incorporated by modelling the search behaviour of the employees across the regions, based on Pilegaard and Fosgerau (2008). However, this modelling approach is extended to take into account the presence of language barriers, given the Belgian context.

In principle, migration between regions could be taken into account assuming utility equalization of consumers between regions. However, we will use exogenous projections of migration, made by the Federal Planning Bureau, instead. For this we are following up the results of MOBLOC, financed by the Federal Science Policy.

- *The transport sector*

The model includes different transport goods. It explicitly models the demand for freight and business transport by producers. Consumer demand also includes the demand for passenger transport, for different purposes: commuting, school and other. In all cases a distinction is made between different modes and time of day. The transport costs consist of both monetary costs and time costs. These are based on the outcomes of the network module. Account is taken of congestion. The flows between the regions are the outcome of gravity models with transport costs as one of the determinants. The gravity models take into account barrier effects due to the presence of a linguistic border in Belgium.

From the literature review we find that the integration between long-term economic models and network models is a novel approach. iTREN-2003, a project financed by the European Commission, is another example of this approach and will be followed-up.

- *Environmental quality*

Environmental quality enters utility in a separable way in the model. This means that it does not have an impact on the behaviour of the economic agents. This is the approach used in most CGE models, though there are some exceptions. The emission factors of the transport sector are based on the environmental module, as are the damages caused by the emissions.

- *Government*

Given the institutional setting of Belgium, the model considers two government levels: the federal and the regional level. Account is taken of the fact that decisions at one level have an impact on other levels. The model includes the main government instruments, with a focus on transport (taxes, regulation, infrastructure). The policy changes that are simulated are assumed to be budget neutral. The choice of a CGE approach allows for an explicit calculation of the full welfare impacts of policy changes, taking into account the impacts on all economic agents.

- *International trade*

Belgium is a small open economy. Therefore, import demand is modelled using the Armington assumption. For export demand a similar approach is used. The basic assumption is that goods produced in different countries are imperfect substitutes. The share of domestic and foreign goods depends on the relative prices in the different countries and on preferences. It is assumed that prices in the rest of the world are exogenous.

Closure is obtained by means of a fixed exchange rate and a flexible current account, which is most realistic for a country such as Belgium.

- *Welfare*

Welfare impacts are computed using a CRIA (Constant Relative Inequality Aversion) welfare function. The change in welfare is computed as the social equivalent gain, obtained as the factor which should be added to each household's equivalent income before the reform to produce a level of social welfare equal to that obtained in the post reform equilibrium. The change in inequality is measured through the Atkinson–Kolm index.

Up to now the modelling work has concentrated on modelling the behaviour of the economic agents at a given point in time. As regards the treatment of dynamics in the long-term economic model, the following lessons were drawn from the literature review:

- *Capital market and investment behaviour*

The main elements driving the evolution of the economy are the capital market and technological change (R&D). Capital depreciation and investment behaviour have to be integrated.

There are two broad ways in which applied CGE models can incorporate dynamics, depending on the way agent's expectations are treated. One is to introduce forward looking expectations, so that agents will maximize their inter-temporal objective functions taking into account future developments. Another is to have agents' expectations depend on past or present parameters, called static of backward looking expectations. In this case a recursive dynamic structure can be preserved, with the economy consisting of a sequence of equilibria. Between these equilibria a selection of variables are dynamically updated, either exogenously or endogenously. Due to their computational simplicity, the last way is commonly used among the models we reviewed. This will also be the approach used in LIMOBEL.

In each year, the model is solved for an equilibrium given the exogenous conditions assumed for that year. The connection between the equilibria is made via capital accumulation. In the reference scenario, the assumption is made that the economy is on a steady-state growth path, with all quantity variables growing at the same rate and all relative prices remaining unchanged. In the alternative scenarios, the implementation of a policy measure causes the economy to enter on a transition path, until, after some time, reaching a new steady-state growth path.

Crucial for the dynamics of the model is the endogenous determination of investment. Investment and capital accumulation in year t depend on expected rates of return for year t+1. These are determined by actual returns on capital in year t. Therefore, the approach implies adaptive expectations. In the dynamic economic processes a homogenous composite investment commodity is allocated between sectors according to the actual (year t) returns on capital in the sector.

Based on the literature review, it was also planned to incorporate capital vintages in LIMOBEL and to assume that, as capital gets older, its flexibility is reduced. However, after consultation with the modelling experts in the follow-up committee we decided to abandon this approach. The main reason is the lack of data. In addition, it was pointed out that the approach would not yield many new insights.

- *R&D and technical change*

In most models, technological change is assumed to be exogenous. This will be the starting point of the first version. Next, we will consider ways to include technological change endogenously, based on R&D expenditures of producers and the government. For this we base ourselves on the survey by Pizer and Popp (2007).

Environmental technologies that exist already but are currently too expensive can be modelled as backstop technologies. Changes in relative prices and development of these technologies may increase their competitiveness in comparison with conventional technologies and allow them to enter the market.

Task 2.2.2: Modelling: data collection

The choice of what to include in the long-term economic model depends to a large extent on data availability. Therefore, the literature review was complemented with an overview of data to be used for the Social Accounting Matrix underlying the CGE model.

For the CGE model the broad framework for the data is given by the National and Regional Accounts that are provided by the Belgian Institute for National Accounts. Moreover, we base ourselves on the supply and use table of the Institute for National Accounts and on the national and regional input-output tables that were constructed by the Federal Planning Bureau. This is a guarantee for the general consistency of the economic data.

Table 3 gives an overview of the main data requirements for the economic model and of the main data sources that are identified at this stage. A lot of data are available, but often from different sources. This implies that the consistency needed to be checked carefully. Moreover, as some interregional data are missing, estimates have to be used rather than data. In our discussion of Table 3 we concentrate mainly on the interregional economic linkages in Belgium. In addition we comment on the household budget survey, the regional government accounts, freight road transport for own account and origin-destination matrices for passenger transport.

Table 3: Main data requirements for the long-term economic model

<table>
<tr><th>Model Element</th><th>Data Requirements</th><th>Data sources + comments</th></tr>
<tr><td colspan="3">Social Accounting Matrix</td></tr>
<tr><td>Production sectors</td><td>Bi-regional input-output tables</td><td>Top-down estimate by FPB</td></tr>
<tr><td>Households</td><td>Regional household consumption by type of product</td><td>Top-down estimate by FPB</td></tr>
<tr><td>Inter-regional trade</td><td>O-D matrix of trade flows by product</td><td>Top down estimate by FPB, but underestimation likely</td></tr>
<tr><td>Government</td><td>- Federal and regional government revenues and expenditures
- Tranfers to population groups, especially unemployment benefits
- Tax/subsidy per type and per product / sector
- Transfers between layers of government</td><td>- HERMREG model (FPB)
- Household budget survey
- Labour force survey
- RVA</td></tr>
<tr><td>International trade</td><td>Regional export and import by product – corrected for re-export</td><td>Top-down estimate by FPB
- Export: by output
- Import: same national import proportions</td></tr>
<tr><td>Capital Accumulation</td><td>- Investments / profits per region per sector
- Historical growth rates of investment per sector</td><td>- Supply and Use Tables (NBB)
- HERMREG model (FPB)</td></tr>
<tr><td colspan="3">Producers: detailed</td></tr>
<tr><td>Inputs of Freight transport</td><td>- Freight flows between regions by mode and type of good
- Matrix of time costs and monetary costs by mode and type of good</td><td>PLANET1 model or Trans-tools project</td></tr>
<tr><td>Inputs of Business transport</td><td>- O-D matrix of business trips by sector and mode
- Matrix of time costs and monetary costs by mode</td><td>No source identified yet</td></tr>
<tr><td>Imperfect competition</td><td>- Number of Firms per sector and region
- Returns to Scale by sector and region</td><td>Bureau Van Dyck data, ECO-DATA, Statistics Belgium</td></tr>
<tr><td>Emissions</td><td>- Amount of emissions per type fuel /input/output and per sector</td><td>HERMES model (FPB)</td></tr>
</table>

Consumers / households		
Different labour types	Skill type Per region	- Labour force survey - Socio-economic survey 2001
Income distribution	Per region	- Household budget survey - SILC - Statistics Belgium
Spending by income groups	Per type of good/service	Household budget survey
Household saving by income group		Household budget survey (but only imperfect indication)
Passenger transport	- O-D matrix of passenger trips by purpose and mode - Matrix of corresponding time costs + monetary costs	PLANET1 model (for commuting and school)(based on socio-economic survey of 2001)
Durables – non durables linkage	Expenditure on durables (cars) + related spending on non-durables	Household budget survey
Labour Market		
Average gross earnings	Per sector and skill type	Statistics Belgium
Inputs of Labour	Number employed, by sector, skill type	Labour force survey
Commuting	- O-D matrix of commuting trips by mode - Matrix of time and monetary costs of commuting trips	PLANET1 model (based on socio-economic survey of 2001)
Interregional migration	O-D matrix of immigrants	Statistics Belgium + demographic projections FPB
International migration	Net migration by region	Statistics Belgium + demographic projections FPB
Unemployment modelling according to Pissarides	- Number of vacancies - Cost of posting vacancies - Probability to find a job per skill level - Regional Beveridge curves	NBB, RAV/ONEM,VDAB, Actiris,Forem
R & D and human capital accumulation		
Backstop technologies	- Shares of production inputs and fixed start-up costs per firm - forecast of the price development of conventional fuels	EPPA model FPB energy projections
R&D	- R & D spending per sector, per type of R&D, per region - New patents per sector per region - Econometric evidence on regional and national spillovers (impact on TFP of R&D in other region/country)	- Eurostat - NEMESIS model (international)(FPB)

Regional data for Belgium

The bi–regional Input-Output (IO) tables of the FPB are the main source of regional data for Belgium. They describe the input–output structure of the economy as well as interregional economic linkages and have been constructed for the three Belgian regions. Given their importance to the model, a brief survey was made describing their method of construction, drawbacks and possible solutions.

The regional IO tables are the result of a top down estimation procedure, disaggregating the national IO table of 2003 to the regional level. This is based on data for regional production, value added and employment figures from the regional accounts. In the final version, the government accounts of the regions and communities are used to regionalize government consumption and the Household Budget Survey is used to provide regional consumption estimates.

IO transactions are obtained by assuming the same input structure per region and thus by applying national IO coefficients to the three regions. Interregional trade flows have been obtained using the Single Location Quotient (SLQ) method. The analysis of the results shows two main caveats of this approach, given the aims of LIMOBEL.

First, the production figures of the regional accounts assign production to the region of the administrative seat of companies. In the case of multiregional companies, this method will lead to a biased picture of regional production. Production in Brussels is likely to be overestimated, while the opposite is true for production in other regions. This problem is difficult to address, given the scarcity of data on regional production by firm branches.

Second, the analysis of the SLQ method for other countries has shown that it may lead to an underestimation of interregional trade flows. A first analysis suggests this to be the case for the Belgian IO data too: The Flemish region exports only 8% of its GDP to the other Belgian regions, while the corresponding figure for Wallonia is only 9%. Conversely, the combination of overestimated regional production figures and the SLQ method may lead to an overestimation of interregional exports from Brussels. The fact that trade in services in the bi-regional IO tables is actually more important compared to trade in goods may be another indication of problems.

The second problem could be remedied by using available data to re–estimate interregional trade. We have analysed two approaches to remedy this problem. The first one is based on the use of interregional freight flow data. However, these may suffer from the existence of hidden imports – flows registered as interregional which are actually hidden international imports. Moreover, it is suited less for interregional trade of services. A second approach is to use the coefficients of gravity models estimated for freight flows (including dummies for the harbour effect), international trade or for interregional trade in countries where more data are available. This second approach will be used.

For trade in services we do not explicitly model the interregional trade flows. Total demand is assumed to equal total supply at the Belgian level. This is the same procedure as the one that is used in the GEM-E3 model for Belgium. We continue to search for a better solution in the literature.

The household budget survey

The incorporation of several household groups in the long-term economic model requires information on the behaviour of these household groups. This information is taken from the Belgian household budget survey. The data were made available in December 2008. For this part of the project the FPB collaborates with an internal FPB project.

Regional government accounts

A first version of the regional government accounts was constructed, based on publicly available data and consistent with the input-output tables. However, some assumptions needed to be made. At the FPB a more in-depth analysis is currently being made by another team. Once these data are available, they will be integrated in LIMOBEL.

Freight road transport for own account

In the supply and use tables transport for own account is included not in the form of intermediate consumption of transport services, but in the form of intermediate consumption of inputs to produce these services (fuel, maintenance etc.) and the input of labour. The supply and use tables need to be adapted in order to isolate the use of transport for own account. For this we build on the expertise that was developed in a project of the FPB on the construction of transport accounts and on previous modelling work.

Origin-destination matrices for passenger transport

The socio-economic survey of 2001 allows for the construction of origin-destination matrices for commuting and school transport. However, no such data are available for the other trip purposes. Informed assumptions will need to be made, based on for instance the TRANSTOOLS database.

2.3. Workpackage 3: Linking the Transport Projection Model and the Network Model

Important note: a synergy was made possible between the DSSITP and LIMOBEL projects in order to permit a faster and more in depth update of the used networks and demand matrices.

Task 3.1: Cost functions

As usual, generalised costs, which integrate several relevant decision variables for transport decision making translated into monetary units, are used. The generalised cost can contain costs related to the moving of a vehicle, the inventory costs of the goods during transportation and other time related costs, handling and storage costs and the costs of the services directly linked to transport and all the residual or indirect costs which are generally evaluated on an average basis.

Most of the used cost functions do not take sufficiently into account time related issues. The total time can be estimated as the sum of the durations of all the operations involved in moving goods from an origin to a destination. The travel time can also be measured as the ratio of distance to average speed. For service based transport modes (such as railways), waiting time is directly related to the frequency. The waiting time for a vehicle can be computed using the frequency q and the planning period H, so that $T_{waiting} = q/(2H)$.

Once the total time of transport is known, it has to be translated in a monetary value. We have used the values made available by NEA, Eurostat and the European project UNITE.

For passenger transport it was chosen to calculate the perceived value by the user for a given trip. The method is based on an analysis of the transport alternatives, i.e. the use of different modes or possible routes.

It was decided to use the results of the HEATCO (Harmonised European Approaches for Transport and Project Costing Assessment) project (2005). This meta-analysis is based on 77 studies in 30 countries for passenger transport.

Some work was also performed in order to take congestion costs into account. Based on the work of Prud'Homme (1999), the methodology we are currently testing includes directly the cost of congestion in the cost functions, instead of using equilibrium assignment algorithms, which are proven not to give reliable results on inter-regional trips and aggregated demand matrices.

An estimate of the demand for the network usage is however needed, and can be inferred from data provided by the Belgian Federal Administration via its "Road traffic data for 2005".

Task 3.2: Methodological issues concerning Virtual Networks

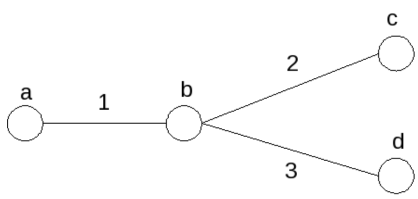
Strategic transport models are still imperfect and many refinements can be proposed. Trains for instance, have to follow a predefined planned route, which can differ from the shortest or cheapest one, and is thus not identified by shortest path algorithms. As a consequence, the cost of the computed path can be lower than the cost on the real route. Beside the fact that the flows are not correctly rendered by the models, the total costs for rail transport is often underestimated and, in multi-modal models, the market-share for rail can be overestimated.

The line concept is defined by Delorme (2003) as an ordered sequence of links and nodes along a path. In this definition, the origin node of each link must coincide with the destination node of the preceding link. Generally, the route followed by a train coincides partially or totally with a set of lines. Note that the line concept can obviously be used in passenger transport models, in order to model bus lines for instance.

Railway lines are seldom (or never?) taken into account in large strategic multi-modal network models. It is claimed that their implementation only has a limited impact on the results. The real reason is probably that not many, if any, multi-modal models are able to conveniently mix free flows (trucks for instance) and "line" flows. Lines are however modelled in most tactical or operational railway models such as CAPRES (Lucchini *et al*, 2000) or FASTA (Curchod *et al*, 1992).

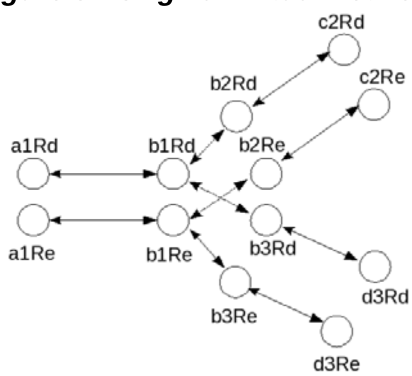
A simple geographic network (Figure 2) does not provide an adequate basis for detailed analyses of transport operations as the same infrastructure, link or node, can be used in different ways. To solve this problem, the basic idea, initially proposed by Harker (1987) and Crainic *et al.* (1990), is to create a virtual link with specific costs for a particular use of an infrastructure. The concept of "supernetworks" of Sheffi (1985) who proposed "transfer" links between modal networks, also provides a somewhat similar framework. Nodus proposes a methodology and an algorithm which creates in a systematic and automatic way a complete virtual network with all the virtual links corresponding to the different operations which are feasible on every real link or node of a geographic network.

Figure 2 : "Real" railway network



In the original definition of the virtual networks (Figure 3), a virtual link was created for every possible transportation means on a real (modal) link. For instance, diesel and electric trains can be used on a given railway chunk. The associated real link (the railway chunk) with multiple means (the types of trains, i.e. diesel and electric) is split in the virtual network into two virtual links, each one corresponding to a unique means, having its specific costs. Moreover, at every node where different directions can be taken, only the links with the same mode and means are connected together.

Figure 3 : Original virtual network



With the integration of the line concept (Figures 4 and 5), the basic ideas is now that a virtual link is created not only for every possible means, but also for every line that uses this link. The methodology can be applied to freight and passenger transport. We are currently working on the model of the Regional Express Railway service project around Brussels. This is ongoing work, and it is too early to present the results of this rather complex model. However, the "line" methodology has been tested and validated on another case, for which the needed data was available. The « C » Railway Corridor (Antwerp / Basel-Lyon), with a total length of about 1840 km, goes through Belgium, the Grand Duchy of Luxembourg, France and Switzerland. This is a strategic corridor for transporting cargo since it connects Antwerp, one of the biggest European ports, to industrial centers.

Figure 4 : Real network with two lines

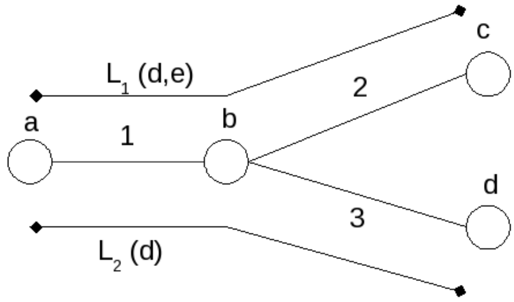
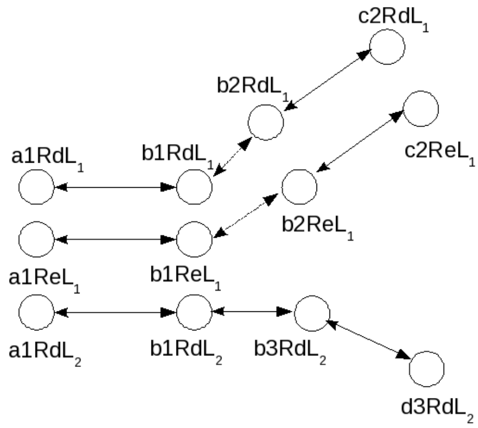


Figure 5 : Virtual network with line implementation



The fastest railway route (Figure 6, dark lines1) between Antwerp and Lyon goes along Paris, while all the trains are expected to go to the South of Belgium (Athus), before running further to Lyon or Basel (Figure 7), which is the real planned route. The spread of the flows is clearly different between these two maps, even if the lengths of both railway routes are almost the same.

Figure 6 - Free-flow routes on the C corridor

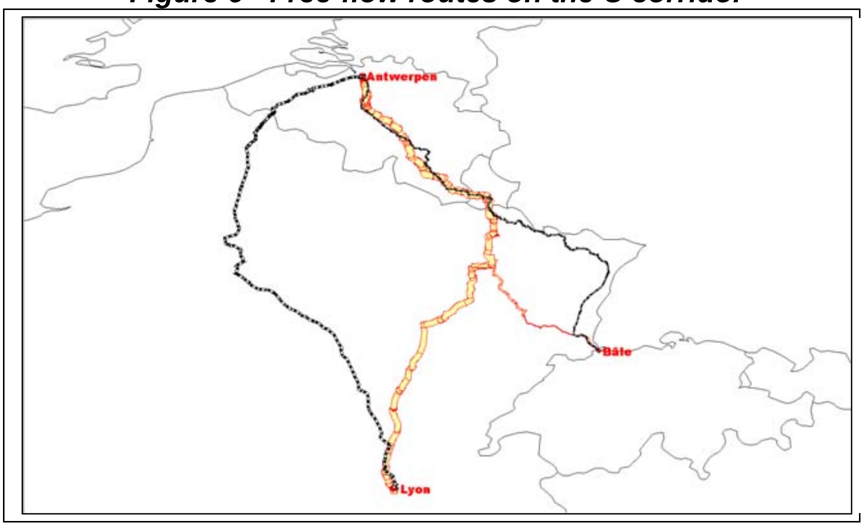
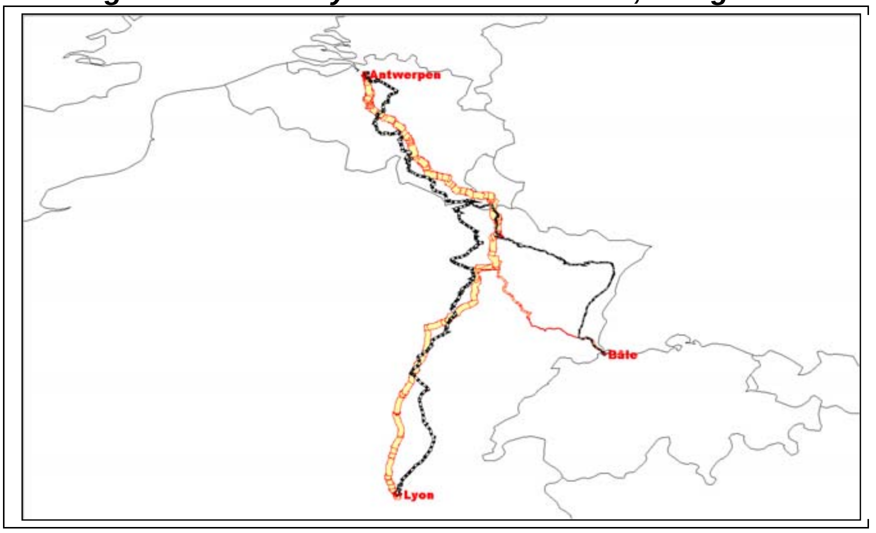


Figure 7 - Correctly modelled C corridor, using lines



The introduction of the line concept in Nodus is described in more detail in a paper that is included as an annex to this report (Annex 2A).

Task 3.3: Demand

A passenger demand matrix for 2001 containing the 589 NUTS5 Belgian regions (corresponding to municipalities) and the Rest of the World was made available for GTM by Statistics Belgium. The matrix is built on the basis of the Socio-Economic Survey that was conducted by Statistics Belgium in 2001. This matrix is detailed by transportation mode (car, train, bus, tram, metro), by trip purpose (commuting, school), and by peak and off peak. Additional work is needed to include other trip purposes. For freight, a set of matrices was also set-up for 2000 at the same level of granularity, and for the 10 main chapters of the NST-R classification of goods. We hope to obtain more recent data in the coming months, coming from the Trans-tools project. Note that this work was originally planned for the years 3 et 4.

Task 3.4: Supply

Road and rail networks are available from the Digital Chart of the World (DCW, 1993). The database was handled in order to be integrated in Nodus, but the networks needed to be validated and updated. This task is mainly based on manual error detection using simple methods and available tools. First, the road and the rail networks provided by ESRI with ArcGIS 9.2 – which are more recent (2005) but less accurate for road – have been used to control the main roads and railroads. The method consists in stacking the DCW with ESRI data in Nodus in order to locate differences between them. Google Maps was used afterwards for final validation. However, this method is not sufficient because it does not take into account the secondary roads and some errors that are too small to be detected. So assignments were performed on a sample of origins to all the possible destinations in order to control and validate the proposed itineraries.

As the road network provided by the DCW is not accurate enough for a study at the NUTS5 level in Belgium, it has been further completed at the regional level for Belgium.

Because the inland waterway network is not available in DCW, it has been digitised manually and controlled using the same method as the one outlined above.

2.4. Workpackage 4: The Environmental Impact Assessment Model

Task 4.1: Interface with WP 2 en WP 3

Within this task VITO fulfilled its contribution to the definition of links between the three model components of LIMOBEL. See Task 1.1 for the result.

Task 4.2: Emission model for road transport

Update of historical fleet data

The approach for processing Belgian statistical data on fleet composition (DIV) has been adjusted (Task 4.2.1). The handling of rough data on road vehicles of the FPS Transport and Mobility is further computerized to be used as direct input in the emission module. The vehicle fleet is region specific. For passenger cars we added a separate category for small diesel cars (< 1400 cc).

Initially, we wanted to base the classification of new vehicles in euro-classes on statistical data (DIV) from 2000 on. Unfortunately, the detail information on euro-classes turned out to be useless. Data are not available for all new vehicles, and even if available, unrealistic figures could appear. So, we decided to apply our previous methodology based on the implementation date of European emission directives for new vehicles. Hereby, we expect that new technologies are introduced some months before directives come into force. Furthermore, we take into account the number of euro 4 diesel passenger cars equipped with a particulate filter. The whole data process has been completed for the Flemish vehicle fleet. For the other regions, some data for the bus fleet are still missing.

Modelling the distribution of trucks in different weight classes

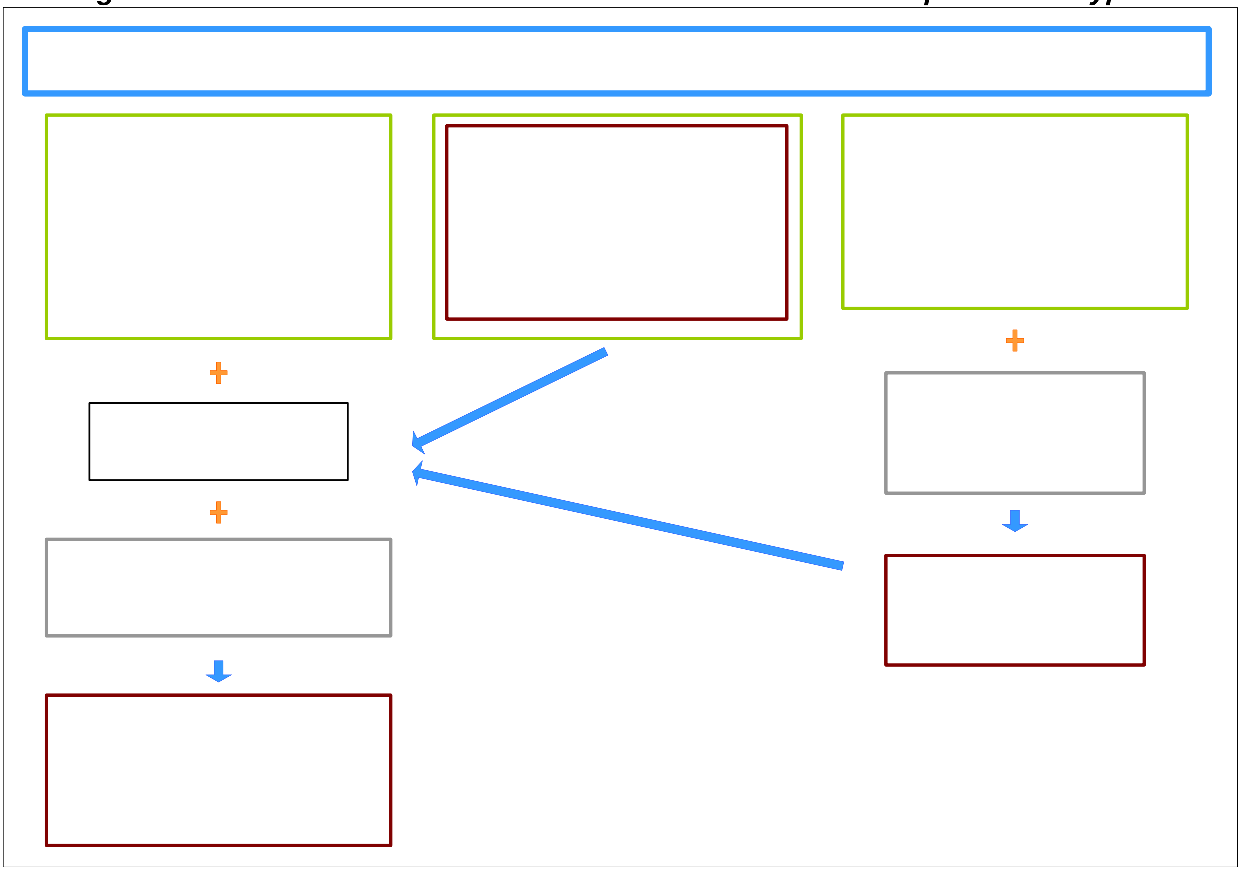
VITO has set up a methodology to divide trucks into different classes depending on the gross weight of the vehicles (Task 4.2.2). The classes correspond to those applied in COPERT IV (EMEP/CORINAIR, 2007):

- rigid (HDVr)
  - 3,5t-7,5t
  - 7,5t-12t
  - 12t-14t
  - 14t-20t
  - 20t-26t
  - 26t-28t
  - 28t-32t
  - 32t-40t
- articulated (HDVa)
  - 14t-20t
  - 20t-28t
  - 28t-34t
  - 34t-40t
  - 40t-50t
  - 50t-60t

This classification process is an important task within WP4 as the national vehicle statistics (DIV) give no complete insight in the composition of trucks in weight classes. E-motion defines the rigid and articulated vehicle stock (COPERT IV) as respectively the rigid trucks and trucks for combination truck-trailer from the DIV statistics. For rigid trucks all information on maximum mass is available in these statistics. But this is not the case for the combination truck-trailer, for which only the mass of the truck is reported in the national vehicle statistics (DIV). VITO has received data on maximum drag from the FPS Economy and their permission to apply the data. This has enabled us to distribute the articulated vehicle stock over the appropriate weight classes of COPERT IV.

Figure 8 shows an overview of the sources and interactions to calculate the historical vehicle kilometres per vehicle type.

Figure 8: Sources to calculate the historical vehicle kilometres per vehicle type



E-motion assigns the vehicle kilometres of the 'rigid trucks' and the 'trucks without trailer' to the rigid vehicle stock, and the vehicle kilometres of the 'truck-trailer' and 'articulated trucks' to the articulated vehicle stock. Tabel 4 presents the results of the calculations of the vehicle kilometres for rigid and articulated trucks in the different regions.

per reg

Source: FPS Mobility and Transpo

Table 4: Vehicle kilometres and tonne-kilometres of heavy duty trucks per region and type

		vkm [10^9]				tonne-km [10^9]			
Region	**Type**	**1995**	**2000**	**2005**	**2007**	**1995**	**2000**	**2005**	**2007**
Brussels	HDVa	0.05	0.06	0.08	0.81	0.46	0.55	0.73	0.09
	HDVr	0.06	0.07	0.07	0.21	0.20	0.23	0.22	0.07
Flanders	HDVa	2.47	2.92	3.65	32.06	19.56	21.76	28.32	4.16
	HDVr	1.64	2.06	1.72	5.41	4.98	6.19	5.58	1.63
Wallonia	HDVa	1.47	1.83	2.22	17.95	11.43	13.16	16.78	2.42
	HDVr	0.89	1.08	0.96	2.88	2.67	3.13	3.02	0.90
Belgium	*total*	*6.58*	*8.02*	*8.69*	*59.32*	*39.30*	*45.01*	*54.66*	*9.26*

The distribution of the total vehicle kilometres per type over the different weight classes is based on:

- the vehicle stock (as described above)
- the statistical data on yearly travelled kilometres per vehicle per type, differentiated over the age classes, from FPS Mobility and Transport.

Table 5 presents the distribution of the total vehicle kilometres per type over the different weight classes for Belgium. As you can see for articulated vehicles, the vehicles in weight class 34-40 tonne are responsible for more than 95% of the kilometres driven. As for rigid vehicles the major kilometres (94-97%) are driven by vehicles with a gross weight up to 26 tonne.

Table 5: Percentages of vehicle kilometres and tonne-kilometres of heavy duty trucks for Belgium per vehicle type and category

Belgium		**vkm**				**tonne-km**			
Type	**Category**	**1995**	**2000**	**2005**	**2007**	**1995**	**2000**	**2005**	**2007**
HDVa	14t-20t	1%	1%	1%	1%	0%	0%	0%	0%
	20t-28t	1%	1%	0%	0%	1%	1%	0%	0%
	28t-34t	2%	1%	0%	0%	1%	1%	0%	0%
	34t-40t	96%	97%	99%	99%	97%	98%	99%	99%
HDVr	03,5t-07,5t	22%	21%	19%	18%	9%	8%	7%	6%
	07,5t-12t	20%	21%	22%	22%	14%	14%	14%	13%
	12t-14t	10%	6%	3%	3%	9%	5%	3%	3%
	14t-20t	29%	27%	25%	24%	35%	31%	27%	26%
	20t-26t	17%	22%	26%	27%	27%	35%	39%	40%
	26t-28t	0%	0%	0%	0%	0%	0%	0%	1%
	28t-32t	3%	3%	5%	6%	6%	7%	10%	11%
	32t-40t	0%	0%	0%	0%	0%	0%	0%	1%

VITO has calibrated the tonne-kilometres driven by trucks of different weight classes on the basis of aggregated figures for tonne-kilometres available at the FPS Mobility and Transport for the historical years. E-motion calculates with a maximum loading capacity of 60% of the gross weight of the vehicle (rigid truck or truck-trailer) (Labeeuw, 2002). VITO performed calibrations (iterative) per region to get regional load factors up to 2007 (Figure 9).

Figure 9: Regional load factors for heavy duty trucks in Belgium

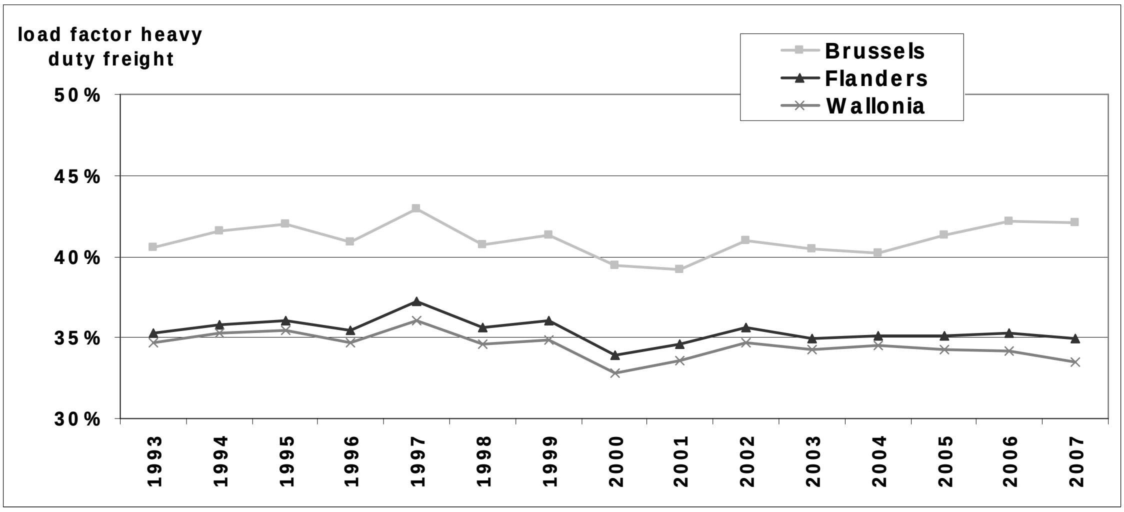
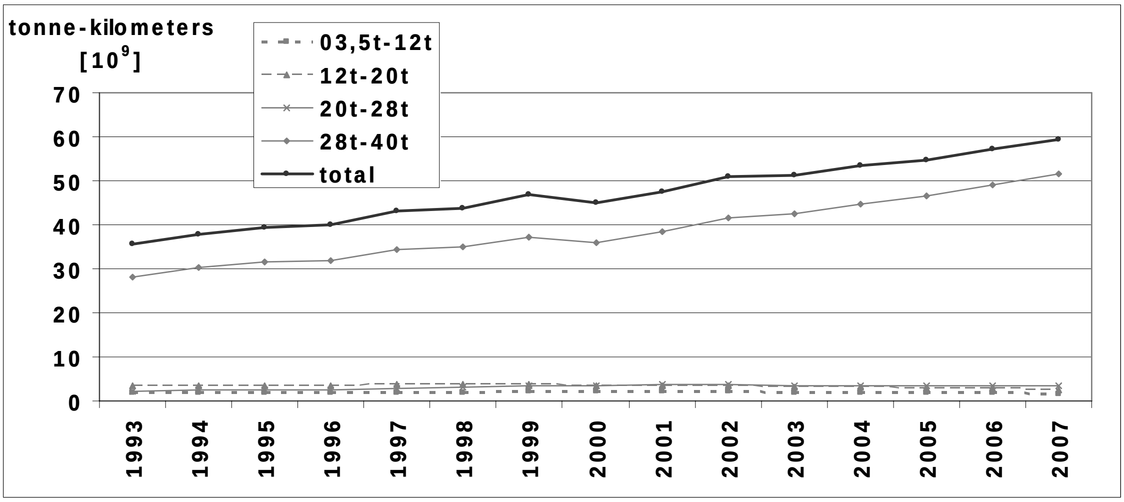


Figure 10 gives an overview of the tonne-kilometres over different weight classes. Trucks - rigid and articulated together - with a gross weight between 28 and 40 tonnes are responsible for on average 63% of the total vehicle kilometres of heavy duty trucks in Belgium over the period 1993-2007 and they transport on average 82% of the total tonnes of goods.

Figure 10: Tonne-kilometres over different weight classes in Belgium



Selection of vehicle and motor fuel technologies

The basis for the selection of alternative vehicle and fuel technologies is formed by the sustainability assessment of road transport technologies by multiple criteria analysis performed with the SUSATRANS project (De Vlieger et al., 2005). We made some changes for light duty freight vehicles: we apply the same technologies as for passenger cars. Furthermore, we foresee the introduction of hybrid technology for trucks under 12 tonnes gross weight (see Table 6). For biofuels we tune to the assumptions made in the BIOSES-project (Biofuels Sustainable End uSe), another SSD project (Task 4.2.3).

Table 6: Overview of the motor fuel and technologies included in the emission module

	Cars	LDV	HDV	busses	coaches	motos
CNG	v	v		v		
Diesel	v	v	v	v	v	
Electric	v	v		v		
Fuel Cell H2	v	v		v		
H2 ICE	v	v				
Diesel hybrid	v	v	< 12 tonne	v		
Petrol hybrid	v	v				
LPG	v	v				
Petrol	v	v				v

Hybrid means that the vehicles are able to drive a certain distance purely on electricity and have the possibility to load their batteries on the net (plug-in) in the future. The micro- or mild hybrid is not incorporated in the hybrid classes, but sorts under the diesel and petrol technologies. Petrol technology also incorporates flexi-fuel vehicles, that could drive on both petrol and ethanol blends.

Within the ('full') hybrid vehicles two types technologies are considered:

- charge sustaining: the battery loses net no charge, all energy is supplied by the combustion engine. Typical example of such a system is the Toyota Prius.
- charge depleting: here there is a net discharge of the battery, it needs to be charged at the electricity grid (e.g. at night). This type is also known as 'plug-in hybrid' (PHEV).

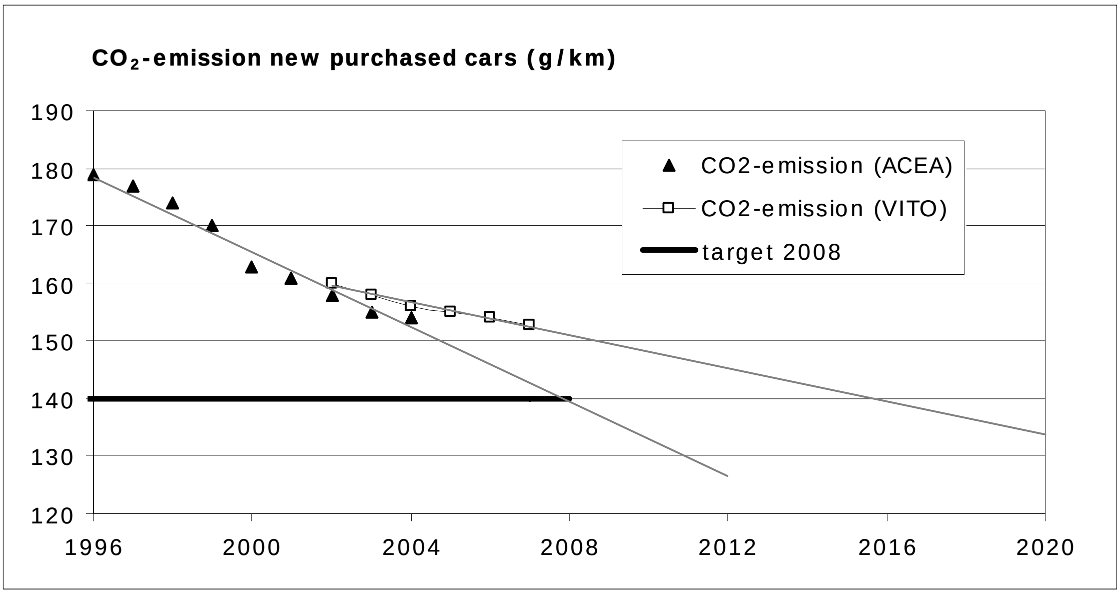
For PHEV vehicles an American study states that the ratio between kilometres driven by the combustion engine and electric engine amounts to 50/50 (Gonder et al., 2007). An Italian study reports a ratio of 30/70 (Harry, 2007). In Belgium the average distance driven by passenger cars is lower than in the USA. In addition, we want to exclude an overestimation of the distance driven on the electric engine. Therefore, for Belgium we assume that 40 % of the kilometres are driven from the combustion engine and 60 % from the electric grid.

Update and extension the emission functions

As regards the update and refining of the emission functions, we rely on the COPERT IV emission functions for the conventional fuels (diesel, petrol and LPG) (EMEP/CORINAIR, 2007). COPERT IV reports only few functions for alternative motor fuel and vehicle technologies: charge sustaining petrol hybrid passenger cars, CNG busses and biodiesel. For the other alternatives VITO integrates its own expertise (measurements and literature) and international network.

For CO_2 emissions from passenger cars, VITO adapts the COPERT IV CO_2-functions, as these do not take into account the voluntary agreement between the automobile manufacturers (ACEA, JAMA, KAMA) and the European Commission to reduce the CO_2 emission of new cars. VITO makes adjustments based on its yearly CO_2 monitoring program on new cars. Per euro class the COPERT-function is differentiated. For the projections the emission module has the possibility to work with effective ACEA targets or a more realistic target (Figure 11). We have uncoupled the amount of efficiency improvement by shift to other vehicles types (small, hybrid,…) and the efficiency improvement within the same category (motor management, mild hybrid).

Figure 11: Trend CO_2 monitoring new passenger cars - Belgium



Furthermore, we performed a literature review on the effect of mobile air-conditioning (MAC) systems on fuel consumption and fuel related emissions of passenger cars (Rijkeboer et al., 2002; Vermeulen R.J. et al., 2005; Clodic et al. 2005; Smokers et al., 2006). On the basis of this review VITO has set up a methodology to quantify the effect of mobile air-conditioning systems and to integrate the effect in the emission module. We take into account: the amount of vehicles equipped with a MAC system, the surplus weight of a MAC, fuel type, the outside temperature and the MAC type. We estimate the effect of mobile air-conditioning systems on fuel consumption, CO_2, SO_2.and lead. For the non-fuel related pollutants, there are only limited data available, so we use the same emission function as for vehicles without MAC system.

We have also developed a sub module to estimate emissions of cooling liquid from MAC systems. Regular and irregular leakages, recharge and end of life emissions are taken into account. For this we have built on the emission inventory expertise of ECONOTEC/VITO (2007). For the projections we take into consideration the European directive 2006/40/EC on the usage of cooling liquid. The general expectation is that the current cooling liquid HFC-134a will be replaced by CO_2, the so-called R744 MAC systems (Clodic et al., 2005; Smokers et al., 2006).

The purchase cost of motor fuel and vehicle technologies

In this section we give a summary of the purchase cost related to the different selected options for motor fuel and vehicle technologies for passenger cars. These costs will be used as an input for the PLANET2 model to quantify the penetration of the different motor fuel and vehicle technologies up to 2030. For the other vehicle categories VITO will supply shares of fuels and vehicles technologies based on the scenarios defined within MIRA-S 2009 (VMM, 2009).

The total purchase cost per motor fuel and vehicle technology is given for the years 2015, 2020, 2025 and 2030 (in euro 2005) in Table 7. This cost also incorporates the cost related to the voluntary CO_2 agreement. Costs are based on the findings within SUSATRANS (Verbeiren et al., 2003). However, VITO has organised an internal expert judgement to adjust the figures to the current state-of-the-art of technology and to the expected evolution on the basis of new insights.

Table 7: Purchase cost per motor fuel and vehicle technology for medium size passenger car (euro 2005)

	Life span	Purchase cost [euro 2005]			
	(year)	2015	2020	2025	2030
Petrol	10	18 595	19 816	20 091	20 520
Diesel	11	19 992	20 561	21 323	21 686
LPG	10	20 795	22 126	22 511	22 940
CNG	10	21 895	22 566	22 841	23 270
Electric	11	26 598	25 652	22 990	21 890
Fuel Cell H2	9	45 815	36 500	27 185	25 300
H2 ICE	9	23 025	23 146	22 871	23 300
Petrol hybrid CS	10	21 540	20 671	20 220	19 780
Diesel hybrid CS	11	23 157	22 237	21 870	21 320
Petrol hybrid PHEV	10	24 730	22 530	21 980	21 540
Diesel hybrid PHEV	11	25 830	23 630	23 080	22 640

Task 4.3: Emission model for rail traffic and inland navigation

In the past VITO did not take into account the technological evolution of diesel engines for rail traffic in its emission models. As a result we mainly focussed on the rail module in 2008. Until now, we performed little work on inland navigation within LIMOBEL. So, in what follows we report on the work done for rail, metro and trams.

Emission model for rail traffic

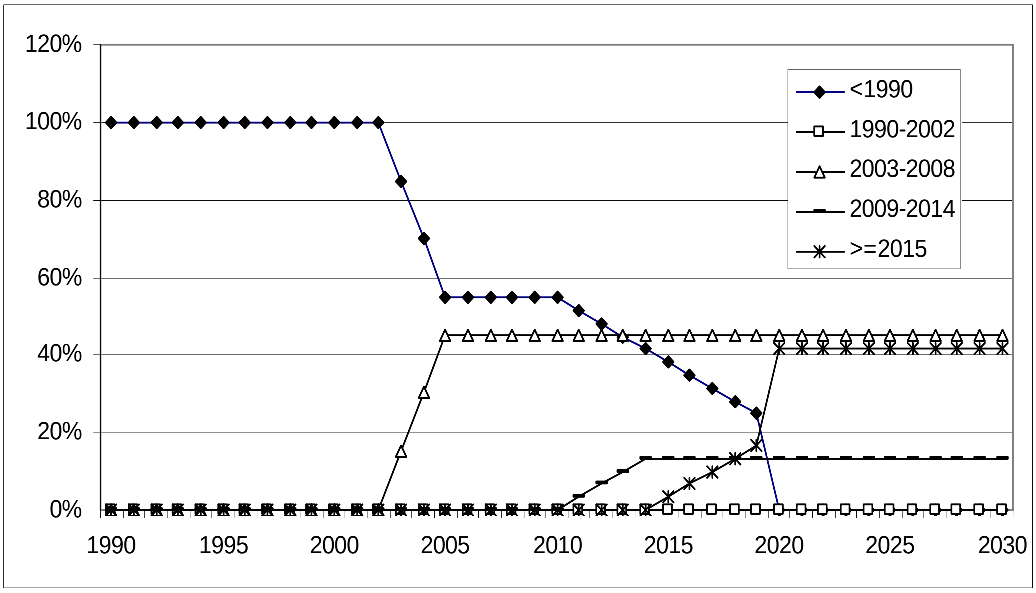
Based upon data sources available for emission factors and existing emission legislation for trains, we defined five age classes (~ technology generations) for the period 1990-2030:

- < 1990 (pre-1990);
- 1990 – 2002;
- 2003 – 200x, UIC 2 (locomotive locomotives x = 8, railcars x = 5);
- 2009 – 2014, 2004/26/EC Stage IIIA (locomotives and 2006 – 2014 for railcars);
- ≥ 2015 2004/26/EC Stage IIIB (locomotives and railcars).

By doing so, the effect of the UIC emission requirements and the European Directive 2004/26/EC on the environmental performance of rail in Europe can be taken into account. In the emission module we introduce Stage IIIA from 01/01/2009 for diesel locomotives and from 01/01/2006 for diesel railcars. As the railway industry is still in discussion with the EC about the postponement of the introduction of Stage IIIB from 31/12/2011 to 31/12/2014, we assume Stage IIIB will become effective on 01/01/2015.

To classify the historical traction vehicle stock we use the national railway statistics. For the projection we set up an age distribution for diesel trains up to 2030 based on the existing investment plans of the Belgian Railway Company (short term) and yearly renewal rates for the long term projections, see Figure 12.

Figure 12: Age distribution of main locomotive – Belgium 1990-2030



Energy consumption figures per gross-tonne kilometre were provided by the Belgium Railway Company making a distinction according to vehicle type (locomotive or railcar), fuel (diesel or electric) and service (passenger: Intercity, Interregional, Local, High speed train and freight).

CO_2 and SO_2 are fuel related emissions and could be easily calculated from respectively the carbon and sulphur content of the fuel used for diesel trains. For CH_4 and N_2O, we apply emission factors from IPCC (2006). For NO_x, PM, CO and HC power specific emission factor are used differentiated for the 5 technology classes (AEAT, 2005; (EMEP/Corinair 1996; and the emission legislation).

Together with the New Cronos database on activities we perform test runs for the period 1990-2030. Our model is calibrated against the CEMT-UIC energy statistics (yearly 1990-2005). The deviation between our calculation and the statistics before calibration amount to 1 to 15 % for diesel and 1 to 8 % for electric energy.

In Table 8 we show some emission results for diesel trains in 2005. In addition, we compare the emissions and diesel consumption for 2005 to figures of TREMOVE and SUSATRANS (De Vlieger et al.,2005).

Table 8: Comparison of emissions from diesel trains – Belgium 2005

	CO_2 [kton]	NO_x [ton]	SO_2 [ton]
SUSATRANS (2005)	127	2 004	3,8
Tremove 2.7 BC (2006)	75	1 333	91
LIMOBEL (2008)	119	1 731	3,6

Table 8 shows that the CO_2 emission is about 60% higher in LIMOBEL compared to TREMOVE. In LIMOBEL we applied statistical activity data until 2005 and we calibrated against the 2005 UIC statistics. The 2005 diesel consumption reported in UIC statistics is 8% higher than the un-calibrated diesel consumption we calculated. For electric energy consumption for rail traction this amounts to 6% in 2005.

Within TREMOVE and SUSATRANS figures for 2005 are not based on statistics, but on projections. Diesel CO_2 emissions from diesel trains in Belgium are underestimated in TREMOVE, as are the NO_x emissions. In SUSATRANS the projected energy consumption and CO_2 emissions are slightly overestimated compared to the UIC figures for 2005. NO_x emissions are higher due to the higher emission factor applied in SUSATRANS. In LIMOBEL we take into account the technological evolution in diesel traction for rail. Furthermore, SO_2 emissions from diesel trains in LIMOBEL and SUSATRANS are low, because of the political decision to use the same fuel specifications for diesel trains as road transport. As a result the Belgium Railway Company has switched to low sulphur diesel (< 50 ppm S) as from 2003.

Module for metro and tram

Information on the vehicle fleet composition, the amount of vehicle kilometres driven and the energy consumption of metros and trams have been requested to the public transport companies (De Lijn, MIVB/STIB and TEC). There is not enough information available to make a distinction between the energy consumption of different vehicle generations. Furthermore, electric engines are very efficient, so further amelioration is negligible. Although, energy consumption varies between different sources, see Table 9. These figures have to be analysed further and complemented with information from the TEC.

Table 9: Energy consumption for trams and metros

In kWh/vkm	Metro	Tram
MIVB/STIB (2008)	4,1	5,6
De Lijn (2001)	-	3,5
INFRAS/TRL (2004)	2,5	4,0

At this moment, we tend to a model for energy consumption taking into account only one type of tram and metro. If desired we could make a distinction between the different regions.

As being electric vehicles, metros and trams have no direct exhaust gas emissions. However, they result in non-exhaust particulate matter (abrasion of the brakes, wheels, overhead wire and rails). For trams emissions factors are given in (Wunderlin et al., 2000; Schrooten et al., 2002).

3. Preliminary conclusions and recommendations

In the first phase of the LIMOBEL project the first task was the identification of the main links between the different model components. These concern the type of information that is communicated between the long-term economic model, the network model and the environmental impact assessment model. A framework was set up for the future work in LIMOBEL (see Figure 1).

Secondly, we have been able to determine the basic set-up of the long-term economic model. We decided on the type of model to use – a conventional CGE model with a regional dimension and different household groups – and on the crucial aspects that should be included in the model. For this we based ourselves on a review of both applied and theoretical models, complemented by a data collection exercise. The construction of the CGE model is currently ongoing.

Thirdly, work was undertaken to obtain an updated and more realistic network model. The result is a better insight in the components of the generalised costs for passenger and freight transport, the introduction of the line concept for rail transport and an update of the network.

Finally, the methodology for the environmental impact assessment model was developed further. This concerns first of all a better data set for the historical fleet:, the distinction between trucks of different weight classes and the selection of new motor fuel and vehicle technologies. Secondly, work was undertaken to update and refine the emission functions, taking into account the results of COPERT IV, together with the impact of air conditioning and the impact of the voluntary agreement between the car manufacturers and the European Commission on CO_2 emissions of new cars. The emission module has been validated on the basis of figures for the Flemish region. Furthermore, purchase costs for motor fuel and vehicle technologies have been determined to apply as an input in the CGE model. In addition, first runs have been performed with the technological emission model for rail traffic.

4. Prospects for the second phase of the project

The next table gives an overview of the deliverables that are planned for the second phase of the project. The paragraphs below give more information on the content of workpackages 2 to 5.

Table 10: Overview of LIMOBEL deliverables in Phase 2

Phase 2	
Deliverable 2.2: Long term economic modelling: model description	x+26
Deliverable 2.3: Long term economic modelling: model calibration and construction of the baseline scenario	x+36
Deliverable 3.3: Building the demand matrices: software module + sources	x+36
Deliverable 3.4: Using available network data to build the Belgian model + maps in Arc Info format	x+36
Deliverable 3.5: The calibrated Belgian network model	x+42
Deliverable 4.2: Environmental impact assessment: emission model description for road transport	x+31
Deliverable 4.3: Environmental impact assessment: emission model description for rail traffic and inland navigation	x+34
Deliverable 4.4: Environmental impact assessment: emission model description for maritime transport and definition of baseline scenario	x+33
Deliverable 4.5: Environmental impact assessment: methodology description of the geographical distribution of the emissions	x+36
Deliverable 4.6: Environmental impact assessment description of external environmental cost model	x+36
Deliverable 5: Cost-benefit analysis of policy packages	x+48
Final Report	x+48
Guidelines for policy makers	x+48

WP 2: Long-term economic modelling

In this task the project constructs a model for long-term macro-economic projections at the sectoral and regional level, with an explicit modelling of the interaction between the economy in general and the transport sector.

In phase 2 the model construction and the construction of the social accounting matrix that was started in phase 1, will be completed. Next, the model will be calibrated on the basis of elasticity information that is found in the literature and on the basis of an empirical estimation of the demand functions of the households. In the last task of the workpackage the baseline scenario will be constructed.

WP 3: Linking the tranport projection model and the network model

From the demand point of view, the biggest challenge for the second phase of the project will be related to the integration of the output of the long-term economic modelling and several other data sources in order to generate up-to-date and coherent origin-destination matrices, both for freight and passenger transport, that can be used in Nodus; Transit transport will probably be the most difficult aspect to cope with, as the economic model does not explicitly handle it; We hope to achieve this work no later than the end of year 3, because the matrices are needed by all the partners of the project.

Fortunately, as stated in the intermediary reports, the validation and extension of the network database is already nearly achieved, using the Digital Chart of the World and other geographical referenced publicly available databases. This opens the way to a possibility to obtain a calibrated reference scenario somewhat earlier than expected and to start the policy package formulation in due time.

WP 4: The environmental impact assessment model

In this work package we further extend and refine the emission and external environmental cost modules to calculate the environmental costs of transport for the policy scenarios.

Task 4.2: Emission model for road transport

The road emission module will be implemented for the Walloon and Brussels regions. Also, the latest adjustments to COPERT IV (January 2009) will be integrated.

Furthermore, VITO already transformed vehicle kilometres of heavy duty vehicles into tonne-kilometres per vehicle type and weight class for the historical years. However within the LIMOBEL project, a transformation of total tonne-kilometres from the NODUS model into vehicle kilometres per vehicle type and class will be necessary. The E-motion model will be extended to perform this reverse calculation. The model will be also extended with the possibility to take into account an improvement in load factor in the scenarios as a result of the PLANET model.

Task 4.3: Emission model for rail traffic and inland navigation

The railway emission module will be further fine-tuned in close consultation with the Belgian Railway Company. Decision has to be made upon technology classes (current 5 technology classes versus type approval approach). Moreover, the module will be extended with non-exhaust PM (abrasion of the brakes, wheels, overhead wire and rails). In addition, the energy consumption and non exhaust particulate matter for metros and trams will be fine-tuned.

Furthermore, the inland navigation module will be extended and refined to a considerable extent. We prefer to apply the EMS protocols (~ maritime module), which admit a better differentiation into technology classes related to different ship parameters.

Task 4.4: Emission model for maritime transport

We will develop a simplified model to estimate the emissions from sea-going vessels per ship type. We will focus on merchant navy ships (coaster and deep sea shipping). The basis will be the detailed emission model per ship as developed within the MOPSEA project (Schrooten et al., 2007). The results of the recent European study Ex-TREMIS will be integrated (Chiffi et al., 2008).

We will define a baseline scenario upon the technological evolution within seagoing vessels (2030). Therefore, we will take into account the IMO and EC regulation upon maritime fuels and emission regulation. Furthermore, we will screen realistic technical evolution beyond the time horizon of the current regulation. A recent Flemish study IMPLIVAART could be of great value (LNE, 2008).

Task 4.5: Geographical distribution of the emissions

A particular aspect of the emission calculation will be the coupling with the transport infrastructure as well as with the mobility data in order to obtain geographically distributed emissions. By doing so, we will be able to differentiate the impact of transport taking into account the geographical distribution of the exposed population and the environment. Therefore, mode-specific emission modules will be designed and developed that not only calculate the total emissions of each transport mode, but also the distribution of the emissions to geographical locations for the whole of Belgium.

Task 4.6: External environmental cost model

When studying cost functions over long time spans it becomes crucial to take into account changes in some of the parameters that we have (at this moment) well defined until 2010. Firstly, we need to model the changing background emissions that influence the chemical transformation of exhaust pollutants in the atmosphere because the fate of 1 g of e.g. NO_x in 2010 and 2030 will be completely different (in terms of the amount of secondary PM formed as well as its effect on ozone titration) (e.g., early attempts in De Nocker et al., 2006; Int Panis, 2008).

We will update data and scientific information regarding the dispersion and transformation of emitted pollutants, dose-response relations and monetary evaluation. Hereby, we will use information from current national and international studies in this field, such as NEEDS, WHO working group concerning the quantification of impacts. Focus will be put on updating figures for components of secondary PM and noise.

We will also apply the demographic evolution that is taken into account in the projection model (FPB) in the external environmental cost module to estimate the physical impact caused by transport emissions. We will build an environmental module to implement all these aspects. The result will be a non-linear time- and place-dependent cost function that can be linked to the transport projection model and the network model.

Furthermore, for the first time a consistent set of environmental external costs due to maritime transport will be estimated (e.g., early attempts in Friedrich and Bickel, 2001). We will make a distinction between sailing at sea and activities in Scheldt and ports. The result will be environmental costs from maritime transport.

WP 5: Cost-benefit analysis of policy packages

The first task in this workpackage consists of the formulation of the policy scenarios to be evaluated in the social cost benefit analysis. This will be done in consultation with the follow-up committee. The policy scenarios are then transformed into policy packages whose effects are simulated in the projection model.

In the cost-benefit analysis the costs and benefits for different economic agents (incl. different consumer groups) are computed, with a distinction between short-term and long-term effects

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6. Publications / Valorisation

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Schrooten L., De Vlieger I., Int Panis L., Styns K., Torfs R. (2008) Inventory and forecasting of maritime emissions in the Belgian sea territory, an activity based emission model / Atmospheric Environment - 42(4)667-676(2008).

Others

Jourquin, B., J. Lechien and J. Pinna (2008), "Lines and Services in a Strategic Multi-modal Freight Network Model - Methodology and Application", paper to be presented at the 48th Congress of the European Regional Science Association,27 – 31 August 2008, Liverpool, UK

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7. Annexes

ANNEX 1: COMPLEMENTARY INFORMATION

- **Annex 1A:** Mayeres, I., B. Jourquin, J. Lechien and I. Devlieger (2008), Links between the LIMOBEL Components: Summary of Discussion, 7 April 2008.

- **Annex 1B:** Mayeres, I., A. Van Steenbergen, O. Ivanova, C. Heyndrickx, N. Van Nuffel, F. Witlox (2008), Literature review for ISEEM and LIMOBEL, 12 March 2008.

ANNEX 2: COPY OF THE PUBLICATIONS

- **Annex 2A:** Jourquin, B., J. Lechien and J. Pinna (2008), "Lines and Services in a Strategic Multi-modal Freight Network Model - Methodology and Application", paper to be presented at the 48th Congress of the European Regional Science Association,27 – 31 August 2008, Liverpool, UK

- **Annex 2B:** Schrooten L., De Vlieger I., Int Panis L., Styns K., Torfs R. (2008) Inventory and forecasting of maritime emissions in the Belgian sea territory, an activity based emission model / Atmospheric Environment - 42(4)667-676(2008).

- **Annex 2C:** Schrooten L., De Vlieger I., Int Panis L., Broekx S. (2007) Forecasting maritime emissions: an activity based approach, Paper presented at Transport - The Next 50 Years, July 2007, Christchurch, New Zealand.