LIMOBEL – LONG-RUN IMPACTS OF POLICY PACKAGES ON MOBILITY IN BELGIUM: DEVELOPMENT OF A MODELLING TOOL[1]

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ABSTRACT

The paper describes a new modelling tool that is currently being developed in the framework of the LIMOBEL project in order to analyse the long-run mobility impacts of policy packages in Belgium. Its aim is to make long-term projections of transport in Belgium and to make a social cost benefit analysis of various policy measures, including pricing instruments, infrastructure changes and regulation. In the modelling tool three existing models are being developed further and linked to each other. The first model is the PLANET2 model, a model for long-term transport projections. It allows for the integration of the two-way interactions between the economy and transport. The second model is the Nodus model, which is being extended in order to cover both passenger and freight transport. E-motion, the third model, is an environmental impact assessment model that consists of an emission model for road, railway and shipping traffic and of an environmental cost model.

Keywords: Long-term transport model, transport network, environmental costs, cost-benefit analysis

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INTRODUCTION

This paper describes a new modelling tool that is currently being developed in the framework of the LIMOBEL project in order to analyse the long-run mobility impacts of policy packages in Belgium. Its aim is to make long-term projections of transport in Belgium and to make a social cost benefit analysis of various policy measures, including pricing instruments, infrastructure changes and regulation.

In the modelling tool three existing models are being developed further and linked to each other. The first model is the PLANET2 model, a model for long-term transport projections, which extends the existing PLANET model of the FPB by including a long-term economic model. This allows for the integration of the two-way interactions between the economy and transport. The second model is the Nodus model, which is being extended in order to cover both passenger and freight transport. E-motion, the third model, is an environmental impact assessment model that consists of an emission model for road, railway and shipping traffic and of an environmental cost model.

Since the development of the modelling tool is still ongoing, the paper focuses on methodological issues. Its structure is as follows. First, we discuss the general set-up of the models that are currently being developed. Next, we describe the way in which they will be linked and illustrate this by means of a descriptive policy example. The final section concludes.

THE LIMOBEL MODELLING FRAMEWORK

Introduction

The LIMOBEL framework basically uses three models:

- PLANET2: a model for long-term transport projections;
- Nodus: a network model for passenger and freight transport;
- E-motion: an environmental impact assessment model.

The three models are linked to each other, but do not optimise simultaneously. However, various inputs and outputs are exchanged between them (Figure 1).

The aim of the PLANET2-model is to construct long-term transport projections and to simulate the impacts of various policy measures. It consists first of all of an economic model for Belgium and its three regions that allows analysing the implications of economic developments for transport use, together with the indirect impacts of changes in the transport sector on the economic system. Secondly, PLANET2 models the trip distribution for commuting and school trips and for national freight transport at the NUTS3-level for Belgium. For the other transport flows a simplifying assumption is made, due to data limitations. Thirdly, the modal and time choice is determined. Transport choices take into account the evolution of transport costs, calculated on the basis of inputs from the network model. Finally, PLANET2 includes a vehicle stock module for road vehicles, which serves as an input for E-motion, and a welfare module, which takes into account the evolution of environmental costs as determined in E-motion.

The aim of Nodus 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. The network model is fed by the changes in the origin-destination matrices determined in PLANET2. PLANET2 also provides information on the long-term evolution of some transport cost components, such as labour, energy prices etc.

E-motion, the environmental impact assessment tool, consists of an emission model for road, railway, inland navigation and maritime shipping on the one hand and an external environmental cost model on the other hand. The main aim of this tool is to provide the latest know-how on fuel efficiency, emission factors and damage per tonne of emissions. It takes into account the outcomes of the network model concerning the number of km travelled on different routes and in different regions.

The set-up of the three models is discussed in more detail in the next paragraphs.

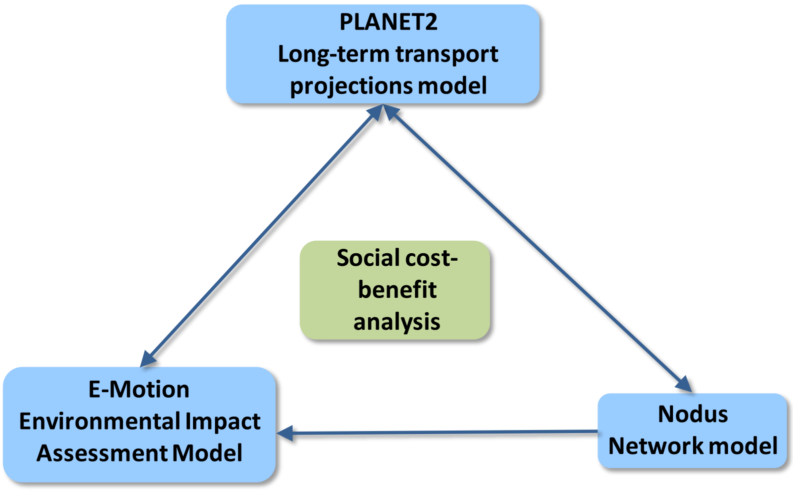

Figure 1: The links between the LIMOBEL model components

The Long-Term Transport Projection Model (PLANET2)

The long-term transport projection model relaxes the assumption that the evolution of the economy is unaffected by changes in the transport sector. For this a recursively dynamic computable general equilibrium (CGE) model for the Belgian economy and its three regions is being incorporated. The model is an extension of the model presented in Mayeres (1999) and incorporates elements of New Economic Geography[2]. The aim is to model both the implications of economic developments on transport use, and the indirect impacts of changes

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[2] Other models belonging to the same tradition are CGEurope (Bröcker et al., 2004), RAEM (Thissen, 2004) and ISEEM (Heyndrickx et al., 2009) and REMI (2007).

in the transport sector on the economic system. Since the focus lies on transport policies, the model includes a more detailed modelling of the transport decisions than standard CGE models. The CGE approach allows for an explicit calculation of the full welfare impacts of policy changes, taking into account the impacts on all economic agents and not only on the transport sector. The discussion in this report focuses on the main features of the CGE model[3], first for a given year, and then turning to the dynamics. A more technical description of the CGE model is given in Mayeres et al. (2010).

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

Households

The CGE model includes different household groups (per region), characterised each by a nested CES utility function which they maximize subject to a budget constraint and a time budget constraint. Based on the Belgian Household Budget Survey, a number of representative household groups are selected. The groups are defined in terms of three criteria: the region, the education level (high and low skilled) and employment status of the head of the household (employed, unemployed, not participating in the labour market). The calibration of the demand functions is based on information from the Household Budget Survey. The inclusion of several household groups allows for an analysis of the distributional impacts of policies. Different consumer goods and services are considered, including transport goods and services. Labour supply is determined endogenously, which is necessary to analyse so-called double dividend issues. For transport a distinction is made between three purposes (commuting, school and other purposes), different transport modes and two periods 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).

Environmental quality and the provision of public goods are taken to enter the utility of the consumers in a separable way. This means that they affect their well-being, but not their behaviour. The emission factors of the transport sector are based on the E-motion model, as are the damages caused by the emissions.

The production sectors

The production side of 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. For all sectors, the producers in each region operate on monopolistically competitive markets and choose the levels of output to maximize profits. Their production technology is characterised by increasing returns to scale. Each regional sector with monopolistic competition contains a certain number of firms, producing slightly differentiated goods and services. Since statistical data describing the production process of the individual firms in the sector are lacking, all firms are assumed to be homogenous and to have the same production technology, the same output size and the same fixed production costs.

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[3] The other features of the PLANET2 model are described in Desmet et al. (2008).

The cost structure of each monopolistically competitive firm consists of variable and fixed costs. Fixed costs are related to its initial establishment in the sector and consist of the costs of fixed capital and labour inputs. Each firm produces one particular variety of the commodity. It sets its price by charging a constant mark-up over marginal costs in order to cover its fixed costs. 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.

The trade sectors

The trade sectors are auxiliary sectors that combine the commodities from the regions of origin with freight transport in order to deliver the commodities to the regions of destination. The trade sectors minimize the costs of ensuring a given level of trade subject to the trade production technology.

The trade production technology is represented by a nested structure. At the top level the trade of a commodity between two regions is a Leontief function of the commodity in the region of origin and the freight transport services composite.

The agents in the region of destination who use or consume the goods (households, government, firms, rest of the world) have widely differentiated preferences with respect to the varieties of the commodities produced by the firms in the monopolistically competitive sectors. They therefore purchase output of all the firms in the sector in the region of origin. The input demand for the a commodity in the trade production function is modelled as a Dixit-Stiglitz aggregate of the different varieties, representing “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. This approach is used only for the domestic regions of origin.

The freight transport services composite is a nested CES function of freight logistic services and freight transport in different locations, by different modes and in different periods. The transport costs consist of both monetary and time costs. Account is taken of congestion.

The labour market

The labour market makes a distinction between two skill types (low and high skilled[4]). Labour supply, i.e. both the number of hours worked and participation on the labour market, is endogenous (Kleven and Kreiner, 2006). Involuntary unemployment is modelled through individual bargaining at the regional level, according to Pissarides’ theory of search unemployment (Pissarides, 2000). Regional vacancies and the unemployed are matched by matching function that are specific to each zone – pair. Matching efficiency declines with generalized commuting costs.

The governments

Given the institutional setting of Belgium, the model distinguishes 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

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[4] The low skilled group includes all people with an education up to a secondary school degree

on transport (taxes, regulation, infrastructure). The policy changes that are simulated are assumed to be budget neutral.

Trade flows
As regards the trade flows, a distinction is made between international and interregional trade. Regional demand is allocated to demand for imports from the rest of the world and the other Belgian regions, using a nested CES function. For export demand a similar approach is used. The basic assumption is that goods produced in different places are imperfect substitutes. The share of domestic and foreign goods depends on the relative prices in the different origins and on preferences. It is assumed that world prices 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.

Dynamics

There are basically two broad ways in which applied CGE models can incorporate dynamics, depending on the way agents' 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 is preserved, with the economy consisting of a sequence of equilibria. Between these equilibria a selection of variables are dynamically updated, either exogenously or endogenously. This is the approach used in LIMOBEL.

In each year, the model will be solved for an equilibrium given the exogenous conditions assumed for that year. The connection between the equilibria is made via capital accumulation. The demographic and technological changes are taken to be exogenous.

Crucial for the dynamics of the model is the endogenous determination of investment. Investment and capital accumulation in a given year (*t*) depend on expected rates of return for the next 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.

The Network Model (Nodus)

A simple geographic network does not provide an adequate basis for detailed analyses of transport operations, as the same infrastructure can often be used in different ways. Thus, there is a need for a better modelling of the functions assumed by nodes, i.e. terminals and transhipment platforms, because the costs of the operations performed at these nodes are important in the total cost of transport. Indeed, a geographical multimodal transport network is not only made of links like roads, railways or waterways, on which vehicles move but also of connecting infrastructures at the nodes like terminals or logistics platforms. To analyse transport operations over the network, costs or weights must be attached to the links over which the goods are transported as well as to the connecting points where the goods are handled. However, most of these transport or handling infrastructures can be used in different ways and at different costs. For example, boats of different sizes and operating costs can use the same waterway; at a terminal a truck's load can be transhipped on a train, bundled with some others on a boat or simply unloaded as it reaches its final destination. Normally, the costs of these alternative operations are different. In order to model this, one of the solutions is to represent each kind of operation in a node as a specific link of a "virtual network", for which a relevant cost is then computed. The basic idea was initially proposed by Harker (1987) and Crainic *et al.* (1990). The concept of "supernetworks" of Sheffi (1985), who proposed "transfer" links between modal networks, also provides a similar framework. The concept was systematised and implemented in a software package (Nodus) by Jourquin (1995) and Jourquin & Beuthe (1996), permitting to apply the methodology to extensive multimodal networks.

In the framework of the LIMOBEL project, two aspects of the latest methodology were improved. First, the concept of lines and services (frequencies) was taken into account. Indeed, trains, for instance, cannot be dispatched using "free" flows, but have to follow "lines", which may be very different from the shortest or fastest route between an origin and a destination. Moreover, trains circulate at a given frequency. Both concepts are however completely ignored in the original definition of virtual networks, because the different virtual links only take the physical characteristics of the real network into account. The definition of the virtual network was therefore modified in order to correctly model lines and services. As a complete description of this improved methodology goes beyond the scope of this paper, the interested reader can find more information in Jourquin et al. (2009). During an assignment, the flows that are transported by "line" modes are now forced to follow the pre-defined lines, while the other modes still can circulate freely. In other words, the new definition of the virtual networks allows to mix "free" and "line" flows inside a single (virtual) network which is an important improvement of the initial methodology. The method was successfully tested on the Belgian network, but will not be implemented at the European level in the context of LIMOBEL, as the necessary input of data is very important (several man/months) and the details of the lines and services for all the countries that are included in the model was not easily available.

Secondly, the LIMOBEL project mixes passenger and freight flows. The assignment methods implemented in Nodus were also improved. Indeed, it was not possible to assign both types of transport during the same assignment. There is now a possibility to easily assign in a single step freight and passenger matrices.

In the framework of the LIMOBEL project, multi-flow assignment procedures are used in the Nodus model, both for freight and passengers. This is performed on the European digitized network, in which the Belgian road network is more detailed compared to the other countries.

For the freight transport matrices, the original data comes from the TRANS-TOOLS project. The data had to be manipulated in order to obtain tables, at the NUTS-5 level for Belgium. Only Belgian national traffic, or origin-destination pairs that are relevant for export/import and transit were taken into account. Note that the TRANS-TOOLS data are available at the NUTS-2 level only. While this granularity can be considered as satisfactory for the other European countries, NUTS-5 data are required for Belgium. To solve this, an attractivity-index for the NUTS-5 zones was estimated for each Belgian NUTS-2 region. This could however be done only on the basis of 1995 data available at GTM (Group of Transport & Mobility, FUCaM). The resulting matrices have a NUTS-2 to NUTS-2 granularity for the transit flows, NUTS-5 to NUTS-2 for export, NUTS-2 to NUTS-5 for import and NUTS-5 to NUTS-5 for all the Belgian national trips.

For passenger transport, the data are based on data made available by the National Institute for Statistics. However, these matrices only pertain to Belgian flows. The original matrices were collected for home-work and home-school flows. Only inter-urban trips were taken into account in the model, in order to remain consistent with the freight O-D matrices.

Anyway, the set of available matrices is not complete. Indeed, for passenger transport, only home-work and home-school trips are available, ignoring all the trips that concern other travel purposes. For freight transport, the flows related to empty trucks are also missing. In order to take into account these missing flows, an innovative method of matrix estimation, based on counts along some links of the network, was developed and applied.

Generating or modifying an origin-destination matrix by means of counts along the infrastructure is a well known problem, although not easy to solve. The method that was developed is based on a rather unique feature of Nodus, which has the ability to save not only the results of the assignment but also the details of all the routes that were computed between all O-D pairs. These details are available even when equilibrium or multi-flow assignments are performed. The principle of the method is rather simple: the original O-D matrix is assigned to the network and then the assigned quantities on each link for which a count is available, are compared with these counts. Then, each O-D pair between which at least one route passed along a link with counts, has its demand modified according to the difference between the assigned and counted flows. This procedure is repeated in a loop until an acceptable global error threshold for the whole assignment (e.g., 2%) is reached.

The objective of the different improvements introduced in Nodus is to build a multi-modal reference model, that will be used as a starting point to model and analyse different policy scenarios.

The Environmental Impact Assessment Model (E-motion)

To evaluate the impact of transport policy on the environment one needs, besides reliable activity data, detailed figures for the technological performance of the fleet. Activity data are provided by the other models in the LIMOBEL framework. Therefore, in the E-motion model we first focus on the historical fleet composition for all transport modes. Then we define feasible options of motor fuel and vehicles technologies for a time horizon up to 2030. Also, average energy consumption and emission factors per vehicle category, technology class and road type are determined to provide input to the PLANET2 model. Furthermore, the external environmental cost module is refined, to take into account the latest knowledge compiled within the NEEDS project of the European 6FP.

Emission modules

E-motion is a technological emission model consisting of different modules, one per transport mode (road, rail, inland navigation and maritime shipping). For each transport mode the technological evolution of the fleet is taken into account. Besides the European and international (for sea-going ships) emission regulations for the fleet, fuel specification is also taken into account. Furthermore, new developments in technologies and fuels up to 2030 are considered.

Emissions can be determined per region or per road/rail/waterway segment, depending on the format in which input data on activities are supplied.

As the road module is the most complex one (see Figure 2), it receives a lot of attention in what follows. The basis for the selection of alternative vehicle and fuel technologies for road vehicles is formed by the sustainability assessment of technologies by multiple criteria analysis performed by De Vlieger et al. (2005). Some adaptations are made for light duty freight vehicles: the same technologies are applied as for passenger cars. For trucks a distinction is made between rigid trucks (RT) and articulated trucks (AT). We foresee the introduction of hybrid technology for trucks under 12 tonnes gross weight. For biofuels we build on the BIOSES-project[5]. Petrol technology also incorporates flexi-fuel vehicles, that can drive both on petrol and ethanol blends.

Within the E-motion model “hybrid” means that the vehicles are able to drive a certain distance purely electric. The micro or mild hybrid sorts under the diesel and petrol technologies. Within the (‘full’) hybrid vehicles two types of technologies are considered. First, the charge sustaining hybrids, which do not have a net discharge of the battery; thus all energy is supplied by the combustion engine. A typical example of such a system is the Toyota Prius. A second option is formed by charge depleting hybrids which have a net discharge of the battery. So, they need to be charged at the electricity grid. This last type is also known as ‘plug-in hybrid’ (PHEV).

Regarding the update and refining of the emission functions, we basically rely on the COPERT 4 emission functions for the conventional fuels (diesel, petrol and LPG). For alternative motor fuel and vehicle technologies only little information is available (EMEP/CORINAIR, 2007). Therefore, for these alternatives we have to integrate our expertise based on own measurements, literature and international network.

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[5] http://www.belspo.be/belspo/ssd/science/projects/BIOSES_en.pdf

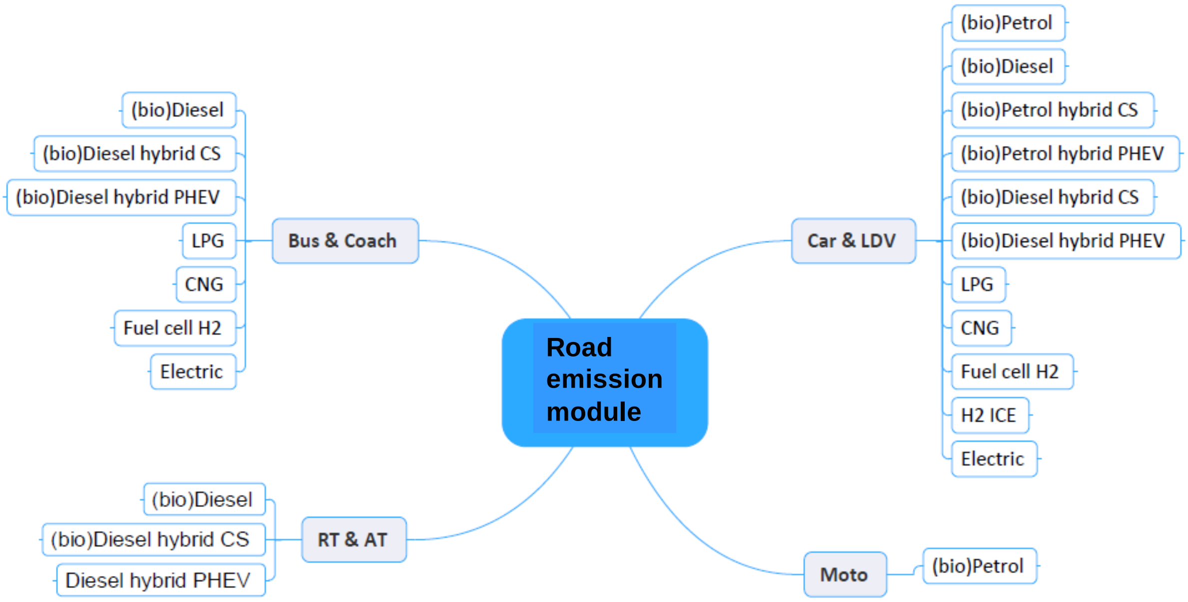


Figure 2: Overview of the motor fuel and technologies included in the road emission module

To fit within the COPERT 4 approach we have distributed the heavy duty trucks into several ton classes. For this exercise we relied on the national vehicle statistics (DIV) and on data on maximum drag received from the FPS Economy.

To come up with more realistic CO_2 figures for passenger cars we extended COPERT 4 with small diesel cars (< 1 400 cc). Furthermore, we adjusted the CO_2 emission functions to take into account the voluntary agreement between the automobile manufacturers (ACEA, JAMA, KAMA) and the European Commission to reduce the CO_2 emissions of new cars. In addition, recent legislation on CO_2 emissions of new cars is taken into account (EC, 2008). For this we have uncoupled the efficiency improvement due to a shift to other vehicles types (small, hybrid, etc.) from the efficiency improvement within the same category (motor management, mild hybrid).

Furthermore, we extended COPERT 4 for the effect of mobile air-conditioning (MAC) systems on fuel consumption and fuel related emissions of passenger cars. For this we take into account the amount of vehicles equipped with a MAC system, the surplus weight of a MAC, the fuel type, the outside temperature and the MAC type. We estimate the effect of MAC systems on fuel consumption and the emissions of CO_2, SO_2 and lead. For the non-fuel related pollutants, the available data are limited, so we use the same emission functions as for vehicles without a MAC system.

For sea-going ships IMO (International Maritime Organisation) and EC regulation is taken into account. Technological improvements of the engines used in sea-going ships are not regulated, but nonetheless present. The maritime module includes differentiated fuel consumption and emission factors depending on the build year of the engine (ship).

Likewise, the module for inland navigation accounts for technological improvements and EC regulations when calculating the energy consumption, fuel use and emissions based on the build year of the engines. Also the rail module considers the technological evolution of diesel engines by taking into account the EC legislation up to stage IIIB (2004/26/EC). To this end, the vehicle fleet is broken down into a number of technology classes according to the EC legislation based on the train type (goods or passengers), the vehicle type (locomotive, multiple unit or HST) and the estimated age distribution.

Consequently, besides the road module, all other modules within E-motion are able to quantify the effect of technological measures on the environmental impact.

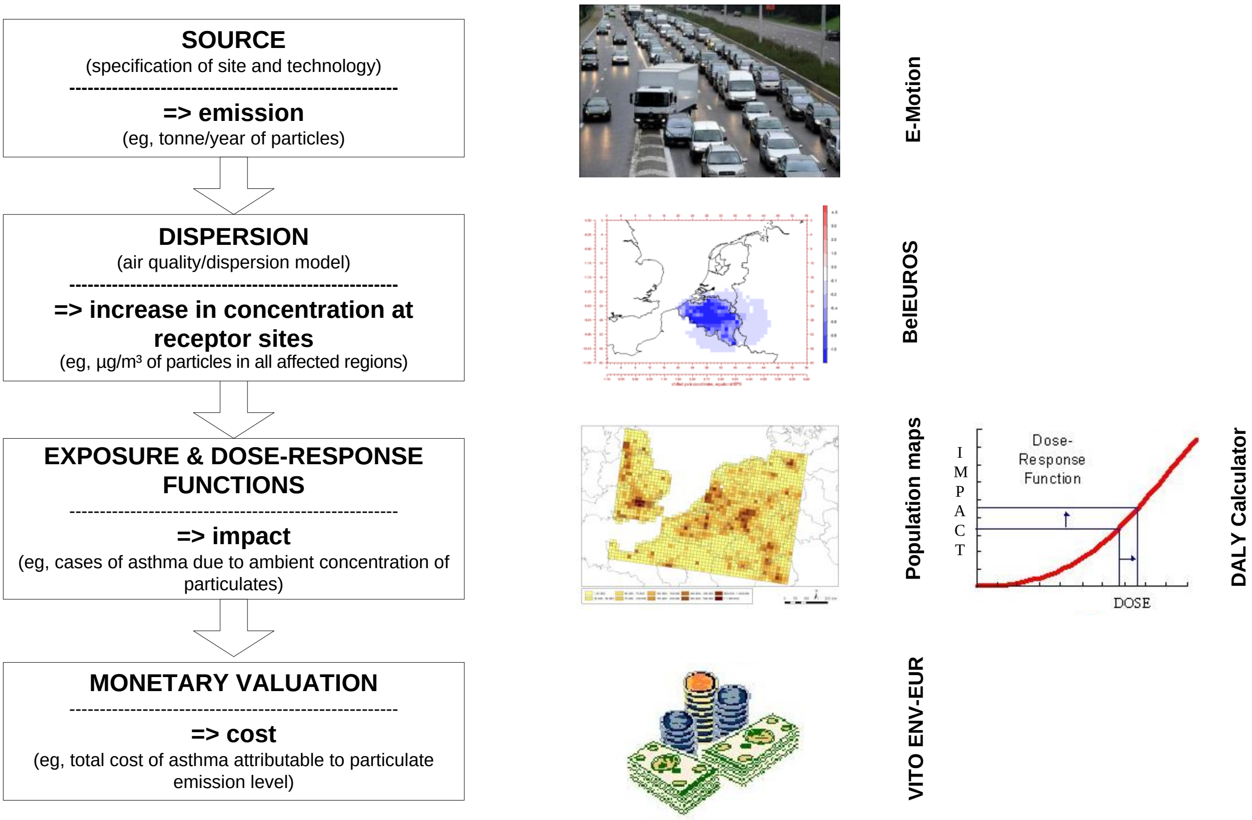
Environmental external cost module

The external cost module starts from the notion that marginal cost figures can only be derived when both a baseline scenario and an alternative scenario is tested. The difference between these two scenarios is that the latter starts from a changed transport emission level of one particular pollutant. The result is a difference in external cost between the two scenarios. We divide this result by the emission difference in order to derive the marginal external cost of each pollutant. We followed this procedure for the major transport pollutants $PM_{2.5}$ and NO_x. Concerning the other transport pollutants like SO_2, NMVOC and PM_{10}, we determined our cost figures on the basis of the literature.

Our calculations are based on the impact pathway method, as developed within the ExternE projects. In this approach, we start from Belgian emission data from our emission model E-motion, calculate concentration maps with the air quality model BelEUROS, take into account the exposed population, and use the result in the DALY-calculator model to find out how big the impacts and costs are. Figure 3 gives an overview of these steps, with the relevant models indicated on the right-hand side.

We were not able to distinguish between a tonne of pollutant emitted in urban areas versus rural or highway areas. Instead, we worked with the total marginal emission change throughout the whole of Belgium. Consequently, the external cost figures presented in this paper represent a value per tonne, averaged over all types of emission locations. Note that the scope of this study includes all transport modes on Belgian territory, going from road transport, railway transport, inland navigation and sea shipping between the Belgian ports, to the LTO cycle for air traffic. We did the scenario calculations for the years 2007 (as a proxy for the current situation), 2020 and 2030.

In our calculations, we took into account a Western European population growth rate which is based on the population outlook of the Belgian Federal Planning Bureau (FPB, 2009). We updated the impact calculation and monetization steps by using the most recent information on dose-response functions and willingness-to-pay values from European projects as ExternE, CAFE (Holland et al., 2005) and NEEDS (Desaigues et al., 2006).



Source: adapted from ExternE (2005)

Figure 3: The impact pathway method

As a result, the marginal external costs for traffic $PM_{2.5}$ emitted in Belgium amounts to 125 kEUR, 131 and 135 kEUR per tonne for the years 2007, 2020 and 2030, respectively. The majority of this cost is attributable to concentrations of $PM_{2.5}$ and PM_{10}.

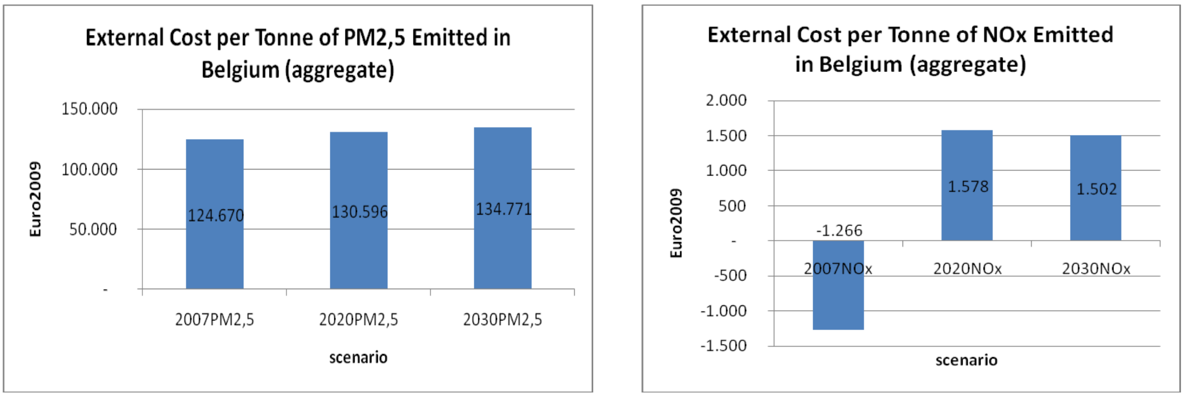


Figure 4: The marginal external air pollution costs related to $PM_{2.5}$ and NO_X

The external cost per tonne of NO_x emitted in Belgium is lower, viz. 1.5 kEUR for both 2020 and 2030, and even negative for 2007 (-1.3 kEUR). A large part of this cost is attributable to nitrate aerosol formation, largely offset by a reduced concentration level of ozone and sulphate aerosols. This is a result of the specific Belgian air conditions, with a low ratio of VOC/NO_x (Deutsch et al., 2009). Following the abundance of NO_x (with NO as its major component), ozone is broken down during the majority of the year. In future years, it is expected that the share of NO in NO_x will decline, whereas the share of NO_2 will rise. Consequently, less NO is available to destroy ozone, and more NO_2 is left to form secondary nitrate aerosols, which will eventually result in a higher external cost.

Besides $PM_{2.5}$ and NO_x, there are some other transport-related air pollutants. In order to find an external cost figure for SO_2, PM_{10} and NMVOC, we conducted a literature review. The numbers mentioned below are based on CAFE (Holland et al., 2005), HEATCO (Bickel et al., 2006) and NEEDS (Desaigues et al., 2006). The costs can be adopted, keeping into account the reliability of these European research projects. For PM_{10}, we calculated a cost of 52 kEUR/tonne, based on the distance distributions over the three different types of road segments. For SO_2 and NMVOCs, we adopt a cost of 14 and 3 kEUR, respectively. These numbers are all in Euro2009 terms.

Please note that all the calculations given in this section are only based on human health impacts (however, the literature review also includes crop impacts). Nevertheless, the proposed numbers are reasonable because of the relative importance of those health impacts in total costs. Moreover, the results for $PM_{2.5}$ are pretty much in line with previous authoritative articles.

THE LINKS BETWEEN THE MODELS

In general, several types of transport policies can be distinguished, including different types of pricing measures, infrastructure changes or regulation. Table 1 presents a selection of policies and indicates the extent to which they are expected to have an impact on the outcomes of the three model components of LIMOBEL. A distinction is made between no impact (0), a small impact (S), a medium impact (M) and a large impact (L). The first two types of policies considered in Table 1 are far-reaching: the internationalisation of external costs and the increase of road speed through infrastructure changes. Their impact will be large in the three LIMOBEL model components. The other three policy types are examples of policies that are more limited in scope, having their main impact in only one or two model components.

Table 1: A selection of policies and their main impacts on the LIMOBEL modelling components

Policy	PLANET2	Nodus	E-Motion
Internalisation of external costs through pricing	Transport generation: M Trip distribution: M Modal and time choice: L Congestion: L Car vehicle stock: L Economy in general: M (via changed transport costs and use of revenues)	Modal choice: L Route choice: L Average speed: L	Average fleet emission factors: L Related environmental damage: L
Infrastructure changes leading to higher average road speed	Transport generation: M Trip distribution: M Modal and time choice: L Congestion: L Car vehicle stock: S Economy in general: M (via changed transport costs, higher investments and financing the investments)	Modal choice: L Route choice: L Average speed: L	Average fleet emission factors: S Related environmental damage: S
Infrastructure changes: a new multi-modal transfer terminal or a new railway link	Transport generation: S Trip distribution: M Modal and time choice: M Congestion: M Car vehicle stock: 0 Economy in general: S(M) (via changed transport costs, higher investments and financing the investments)	Modal choice: L Route choice: L Average speed: M	Average fleet emission factors: 0 Related environmental damage: S
Emission technology regulation for vehicles	Transport generation: S Trip distribution: S Modal and time choice: S Congestion: 0 Car vehicle stock: L Economy in general: S	Modal choice: M Route choice: S Average speed: 0	Average fleet emission factors: L Related environmental damage: L
New mode: supertrucks	Transport generation: S Trip distribution: S Congestion: S Modal and time choice: M Car vehicle stock: 0 Economy in general: (S)	Modal choice: M Route choice: S Average speed:(S)	Average fleet emission factors: S Related environmental damage: S

In order to illustrate the links between the LIMOBEL model components we discuss in more detail how one particular policy can be modelled in the LIMOBEL framework (Figure 5). Suppose that investments by the Flemish government in infrastructure capacity lead to a higher average road speed in Flanders starting from year *t* onwards. This reduces the average time costs of the road modes when they drive in Flanders. The cost-benefit analysis of the measure should take into account the impact on the different consumer groups (including the impact of the change in environmental quality), the different production sectors and the governments at the regional and federal level.

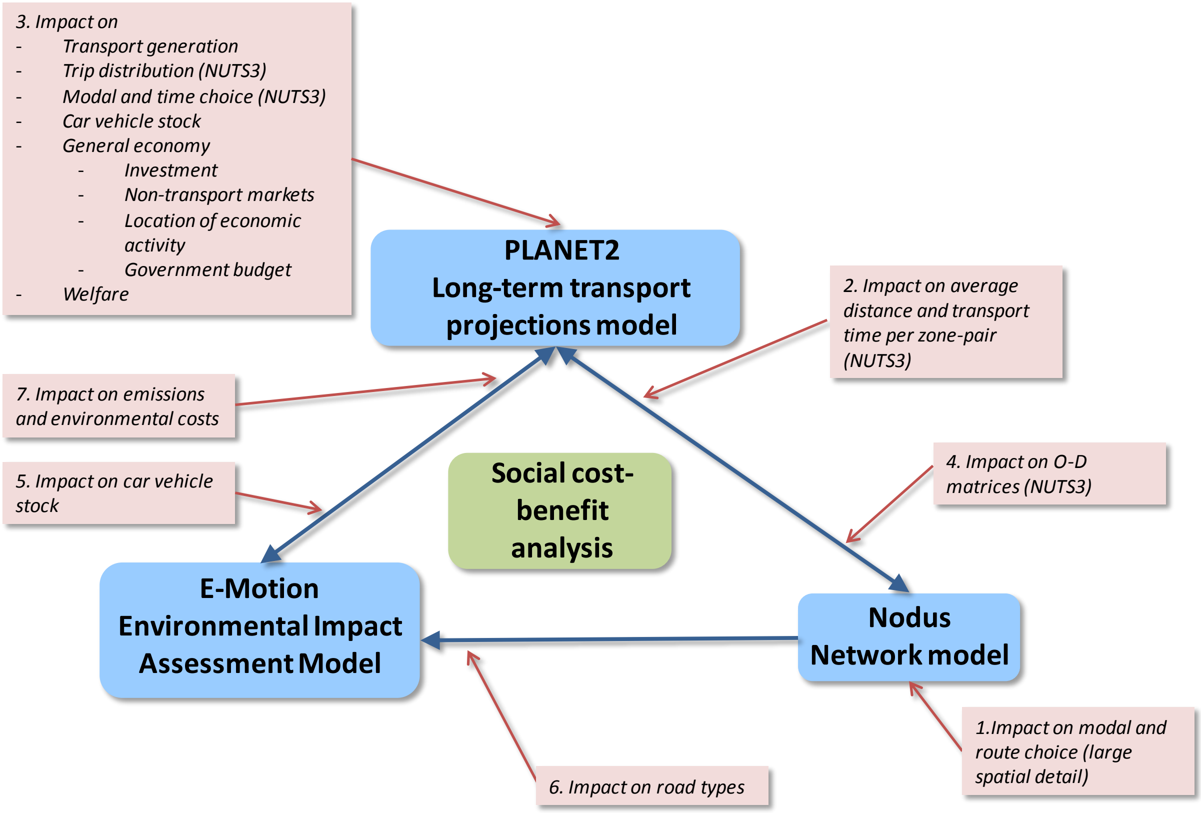


Figure 5: Modelling the impact of road infrastructure investment in one Belgian region

The first impact will be on the modal and route choice in year *t* and is modelled in the Nodus model at a spatially detailed level. The resulting average distance and transport time per zone-pair at the NUTS-3 level is calculated and communicated to the PLANET2 model which computes the transport costs for year *t*+1, combining the information from Nodus with projections on energy prices, wages, etc. On this basis the PLANET2 model determines the demand for transport by both consumers and producers in year *t*+1 (transport generation), the trip distribution at the NUTS3-level (except for non-commuting and non-school trips) and the modal and time choice for year *t*+1. The O-D matrices at the NUTS3-level are communicated to the Nodus model.

The PLANET2 model also computes the impact on the number of road vehicles that results from the change in transport demand. If new vehicles are bought, the average emission factors fall. The impact on the emissions is calculated using E-motion. The total change in emissions and environmental costs depends on the change in transport demand for the different modes and on the change in the average emission factors for these modes. It is calculated with the help of the E-motion model.

The general economy is affected through three channels. First of all, the change in transport costs leads to changes in the transport and non-transport choices of the consumers and the producers. Secondly, the Flemish government invests more in the economy. Thirdly, the government revenue at each government level is affected via changed tax revenues and/or extra spending. If this results in an additional need for government funds, this must be financed by raising taxes, by allowing the deficit to grow (which has implications for its interest payments), or by reducing government spending on other goods or services.

CONCLUDING REMARKS

At this moment the three models and the links between them are still being developed. Therefore, no simulation results can yet be presented. The strength of the LIMOBEL modelling framework that is under development is two-fold; First of all, a quite complete assessment can be made of the impacts of transport policy changes on the transport sector itself, covering both transport generation, trip distribution, modal and time choice, route choice and environmental modelling. Secondly, it allows for an assessment of the impacts of transport policies on the economy in general, on different sectors and income groups. The regional dimension of the long-term economic model makes it possible to evaluate the impact of the policies on the three regions.

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