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FREIGHT TRANSPORTATION PLANNING ON THE EUROPEAN MULTIMODAL NETWORK : THE CASE OF THE WALLON REGION

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Abstract

This paper presents a methodology that can be used for long-run planning of freight transportation on multimodal networks. It is illustrated by a particular research that was performed for the Belgian Walloon Ministry for Equipment and Transport between 1997 and 1999. Its aim was to provide a tool for measuring the impacts of different kinds of policies and/or new infrastructures on freight transport flows in and through Wallonia.

The work started with the setting up of a calibrated multimodal and multi-products reference scenario for the year 1995. This reference scenario was then used as a basis to create a projection for the year 2010: in order to make this projection as realistic as possible, all the decided new infrastructures in Belgium and in the border countries that will be effective in 2010 were introduced in the model. Moreover, expected changes in the O-D matrixes were also introduced at a very detailed level. Then, a set of scenarios was build: one for each transportation mode in which specific changes for that mode were introduced, and one in which the external costs of transport were taken into account.

On the basis of the obtained results, a "transportation plan" was build, in which the most promising changes on the different networks and policies were chosen. A sensitivity analysis (low and high economic activity) was finally performed.

1 Introduction

Medium and Long Run transportation plans at the level of a whole country or region are seldom discussed at a detailed level. This paper presents a methodology that can be used for long-run planning of freight transportation on multimodal networks. It is illustrated by a particular research that was performed for the Belgian Walloon Ministry for Equipment and Transport between 1997 and 1999. Its aim was to provide a tool for measuring the impacts of different kinds of policies and/or new infrastructures on freight transport flows in and through Wallonia.

The work started with the setting up of a calibrated multimodal and multi-products reference scenario for the year 1995. This reference scenario was then used as a basis to create a projection for the year 2010 for which already decided new infrastructures were introduced in the network along with a forecasted new set of O-D matrixes. Then, a set of specific scenarios was built to measure the impact of several new infrastructures or policies. On the basis of the obtained results, a “transportation plan” was built, in which the most promising changes on the different networks and policies were chosen.

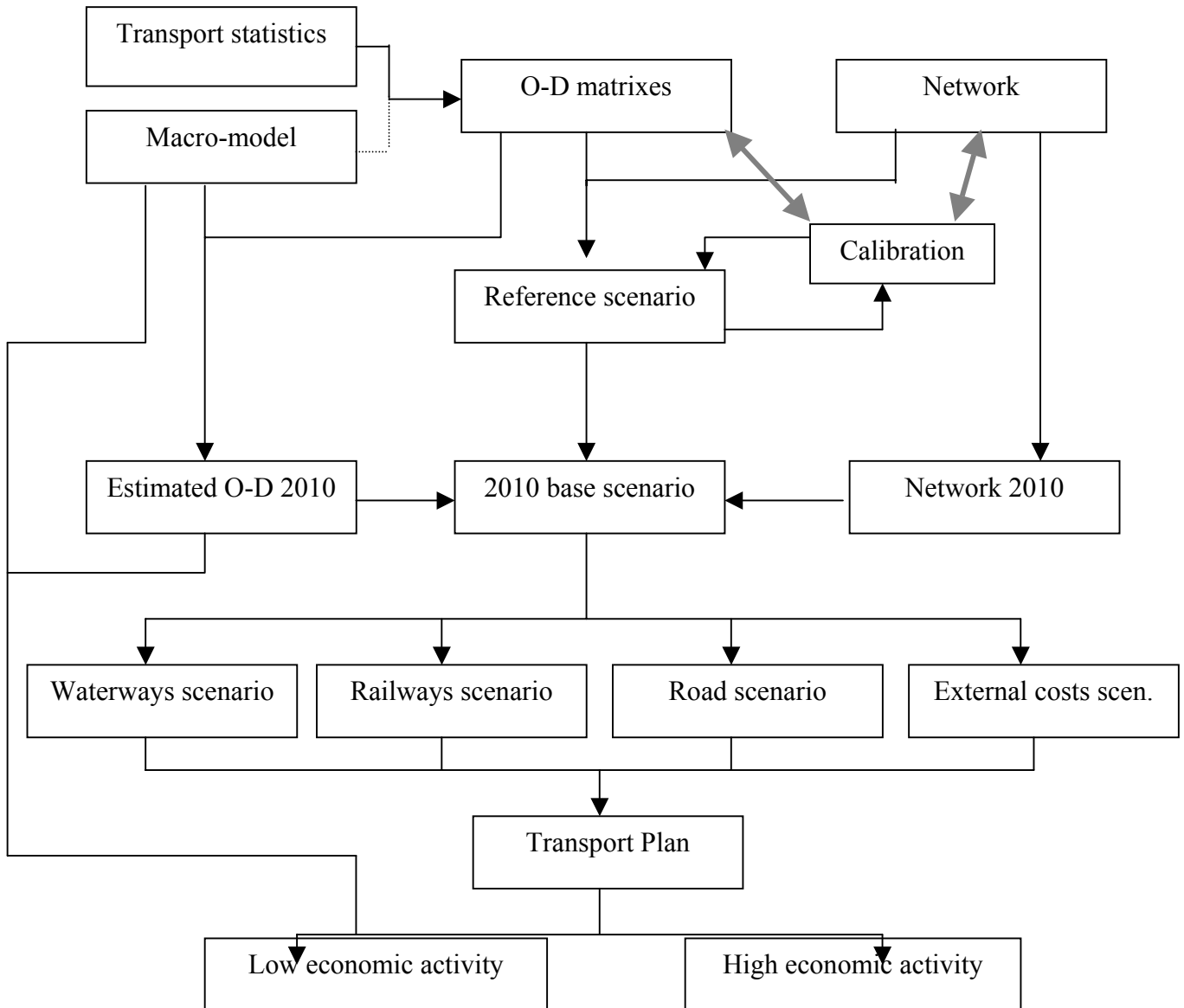
2 Initial motivation and planning of the research

In the second half of the 90’, the Ministry for Equipment and Transport (M.E.T.) of the Walloon Region (RW) was concerned with the development of a transportation plan for 2010 in Wallonia, the French-speaking part of Belgium. Both passenger and commodity transport were to be analysed, but it was decided to separate both models. The freight transportation model was entrusted to a team of consultants (STRATEC S.A. and A.D.E.) and researchers (F.U.Ca.M. – G.T.M.) that also had to provide a software tool to be used at the M.E.T.

The developed model had to correctly assign flows of freight onto the Walloon network on the basis of a demand specified in a set of origin-destination(O-D) matrixes. It had also to perform a satisfactory modal-split. Thus, an important part of the study was devoted to the gathering of relevant data to build the O-D matrixes, the specifications of the network itself and the development of meaningful transportation cost functions.

On this basis, a reference scenario was built, that had to give a good idea of the flows on the network. Once this first scenario calibrated on the observed flows in 1995, the actual “planning” part of the work could begin.

Figure 1: General view of the project



This reference scenario was used in a first step to create a projection for the year 2010: in order to make this projection as realistic as possible, all the decided new infrastructures in Belgium and in the border countries that will be effective in 2010, were introduced in the network model. Moreover, expected changes in the O-D matrixes were also introduced at a very detailed level. This scenario has to be interpreted as a *ceteris paribus* situation in which no new political decisions influence the level of the flows or the modal split.

In a second phase, a set of scenarios was created, each one introducing new policies, new infrastructures, or a combination of both. During this phase, a scenario was proposed for each transportation mode taken separately (road, rail and inland waterways). An additional scenario was concerned with the internalisation of external costs.

Finally, the M.E.T. had to decide which elements of the different scenarios developed during the second phase were to be introduced in the final transportation plan. During this last step,

sensitivity analysis were also performed on the final plan in order to measure its stability against a change in the demand.

It is worth noting that the whole model is installed at the M.E.T. and that several Officials were trained in order to be able to create and analyse new scenarios.

3 Building the reference scenario

3.1 Macroeconomic indicators and demand estimation

The main goal of the macroeconomic model, build up by A.D.E., is to provide a good insight over the evolution of the demand between the different main subdivisions of the Belgian provinces¹, per category of goods in the middle and long run. This model, which can be seen as a spatial and sectorial breaking-up of the macro-economic projections given by the Belgian Planning Office, can be outlined in five steps:

- As the available projections at the macro-sectorial level were only available up to 2005, additional work was done to extend them to 2010.
- Input-Output matrixes were used to split these macro-sectorial projections into sector specific data, by means of a technico-behavioural approach.
- Once all these projections were available, they had to be geographically spread over the ten Belgian provinces. This was done by means of the observed flows and production locations between 1980 and 1994.
- The data were further spread over the “arrondissements”, using national statistics on sectorial employment at this particular geographic level.
- Figures on loaded and unloaded quantities per category of commodities were finally obtained at the “arrondissement” level when a set of ratios was applied to the above data.

In addition to the just outlined procedure, the loaded and unloaded quantities at the different centroids were also estimated by means of transport statistics that were made available by the national railway company, the national office for statistics and the inland waterways administration. This second approach was needed for the transport model, which has much more centroids than existing “arrondissements”.

In effect, the transport matrixes were built mode per mode, before being merged:

- The matrix for the inland waterways could be rather easily built from a database in which all the movements of barges during the year of reference is recorded. The more than 180,000 records were split into five categories of boats. The database contains precise information on the loading/unloading ports when they are located in Belgium. Unfortunately, and this is also the case for the other transportation modes, origins and destinations that are located outside Belgium are only available at the NUTS2 level. As, in many cases, our network contains more than one centroid per NUTS2 region, the relevant amounts of goods were spread among the centroids of a same NUTS2 region by a Monte-Carlo procedure.

¹ Known as “arrondissements” in Belgium.

- The work was much more difficult for the railways, as information on loaded and unloaded goods was only available at the level of some kind of railways administrative regions in Belgium, that sometimes contain more than one centroid (city). A lot of “manual” disaggregation was needed, based on the level of activity of the different firms that are connected to the railway network. Unfortunately, this procedure lead to some loss of information. Indeed, we had no information about flows for which both the origin and the destination are located in the same administrative region. As the origin and destination could very well be located in two different cities, we know that, in some cases, our O-D matrixes underestimate inter-urban railway transports².
- Truck transport was estimated by means of various statistics collected at the national and international levels. The National Office for Statistics continuously collects information about all the trucks registered in Belgium. Some difficulties were to be solved for data collected in the foreign countries as the geographic levels used did not always correspond from country to country. Finally, as no precise information was available for empty vehicles, the corresponding matrix was obtained for these countries by means of ratios obtained for the Belgian traffic. The latter matrix was then tuned using a procedure of matrix-estimation performed after the comparison of the assigned flows on the network with numerous counts made along the Belgian roads.
- A matrix for combined transport was build-up from both the number of containers handled at the different terminals and road traffic observed around these terminals.
- Finally, an existing matrix of origins and destinations for private cars was also used. The pre-load of the network with this matrix will be used later to estimate the level of congestion on the network.

For different reasons, such as for instance a difference between the NACE nomenclature used in the macro-economic model and the NST-R nomenclature used in the transport model, the output given by both approaches gave frequent divergences. As the final output of the research was to provide a GIS transport model, the O-D matrixes obtained by the second approach were used for the assignments. The first matrixes and the macro-economic model were used in a second step to evaluate the impact of the economic activity on the demand: once the impacts evaluated on the “macro” O-D matrixes, they are introduced in the “transport” matrixes.

3.2 Network model

Once the aggregated O-D matrixes are set-up, they have to be assigned on a network. As it was already pointed out in the previous section, it is important to model the Walloon network as an enclave in the European one. The complete European network of “Trunk lines of International Importance” as defined by the European Conference of Ministres of Transport (E.C.M.T.) was digitised. For Belgium, this network was encoded in a more detailed way in order to have the complete networks of railways and inland waterways along with all the

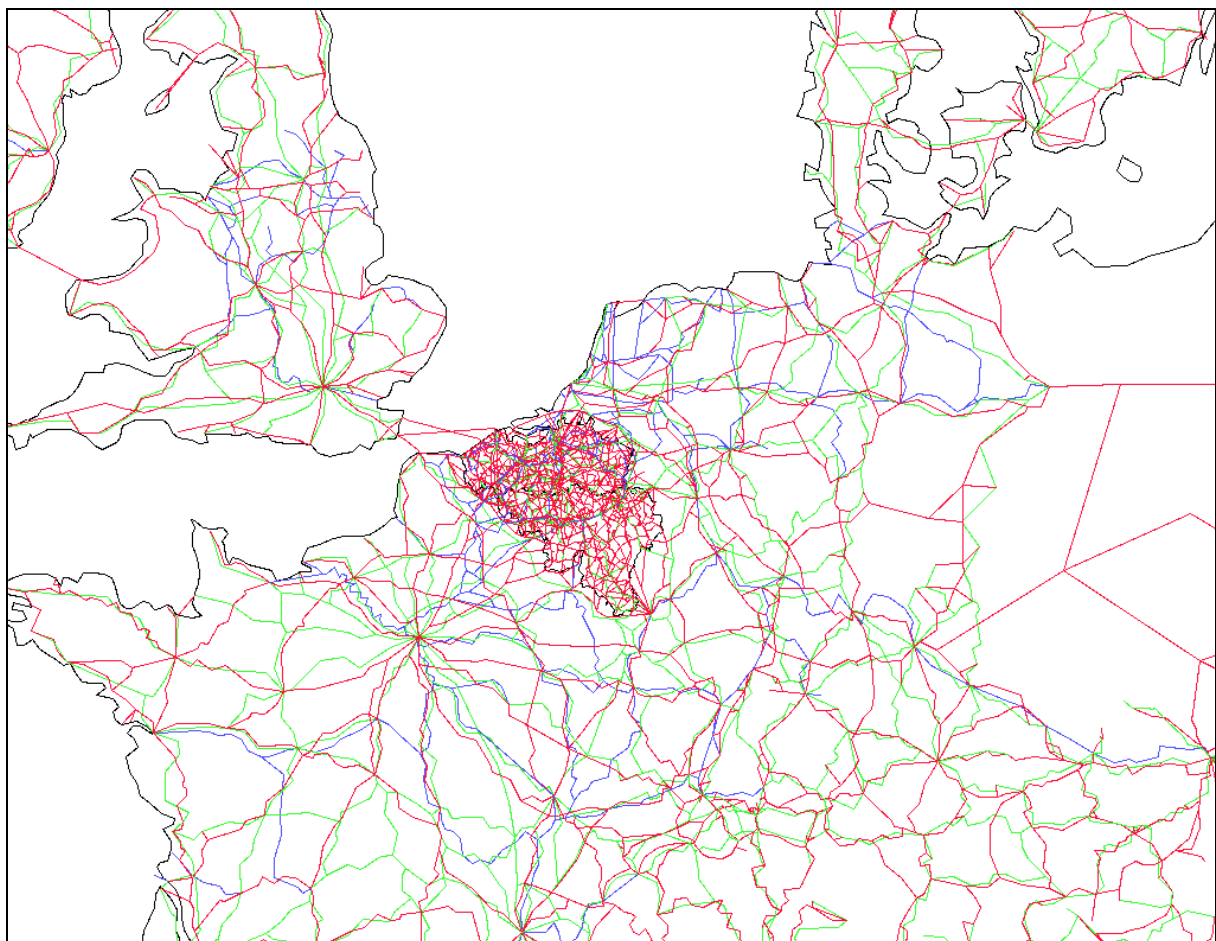
² This is mainly the case for transport of metal products in the administrative districts of Liège and Charleroi.

roads that have a width of at least seven meters. Map 1 gives a partial illustration of the map, in which red links represent the road network. Blue and green are respectively used for inland waterways and railways. The digitised network has about 13,000 nodes and 17,000 links.

The modal choice and assignment of the flows on routes were performed in a single step on what can be called a “virtual network”. Indeed, a geographic network doesn’t provide an adequate basis for a detailed analyse of the different kinds of transports operations (loading, transshipping, transit, ...) that can be performed on a given infrastructure. To solve this problem, the basic idea, initially proposed by Harker and Crainic *et al.*, is to create a virtual link with specific cost for every particular use of an infrastructure. The NODUS software, developed at F.U.Ca.M.-G.T.M. proposes a methodology and an algorithm which creates, in a systematic and quasi-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. The software and its underlying methodology are discussed in Jourquin (1995) and Jourquin & Beuthe (1996).

The freight network were set up with its attributes defining the characteristics of the links and terminals (capacity, speed, terminal facilities, etc.). The data collected to build the O-D matrixes was also useful to limit the (un)loading of the different categories of commodities to the ports and railway station in which they are effectively handled. Moreover, inter-modal transport was allowed for only the commodities that belong to NST-R 9.

Map 1: Part of the digitised network



As usual in transportation analysis (see, for example, Kresge and Roberts, or Wilson and Bennet), NODUS encompasses the concept of "generalised cost" which allows to integrate all the factors relevant for transport decision making in terms of monetary units. The virtual network requires the development of four types of cost functions, which are associated with specific virtual links, i.e., (un)loading, transit, transshipping and moving virtual links. The general methodological framework that underlies the development of specific cost functions for the different transportation modes and means can be found in Jourquin & Beuthe (1996).

For this particular model, specific cost functions were built for five different types of barges (300t, 600t, 1,350t, 2,000t and 4,500t), general cargo trains and large (40t) trucks. The way the model copes with block trains and small trucks will be explained later.

The cost functions are composed of the following elements:

- All the costs related to moving a vehicle between a trip's origin and destination, like labour, fuel, insurance or maintenance costs;
- The inventory costs of the goods during transportation;
- Handling and storage costs, including packaging, loading and unloading and services directly linked to a transport;
- All residual indirect costs like general administrative services which may be assigned to transports on an average basis.

Besides these costs, a full account of transport costs in a multi-modal multi-means context should include some relative costs of transport quality differences, like differential reliability, safety, information, etc, if it is at all possible. These relative costs may vary from one category of goods to another, since transporting cattle or flowers may require different type of care than transporting cement or steel beams. Unhappily, information about these factors is very scarce. They were taken into account to some extent by the adjustment made on cost functions to obtain the best fit of the model (calibration) for each category of goods.

This calibration of the model, i.e., the fit of the assigned flows and the observed one, was performed at three different levels;

- As the O-D matrixes are defined from centroid to centroid, an additional cost for initial and final truck traction to and from a railway station or a inland port must be added to the cost functions for trains and barges. It is this additional cost that is adjusted in order to obtain a correct modal shift. for each category of commodities
- Once a correct modal split obtained, it could still be found that the assigned flows on the network were sometimes different from the counts. To solve these discrepancies, speeds were modified on some links. For example, where a highway and a traditional road are parallel, too much flow can very well be assigned on the latest. Diminishing the speed on it solves the problem.
- As explained earlier, two types of trains can be chosen, but only one cost function was defined because not enough relevant information was found to define two separate consistent cost functions. We decided to consider the cost for a block train as a relative expression of the cost of a traditional train. This percentage was adapted until a correct split between both types of trains was obtained.

A problem remained for trucks as the choice of using a small or a large truck depends much more on the size of the shipment (that is unknown) than on the cost of using both

transportation means. In other words, our cost functions were not discriminant enough to give a satisfactory split. It was decided to solve this problem through a “post-distribution”; the statistics used to build the O-D matrixes were used to estimate, for each category of goods, a distribution of the use of small and large trucks with respect to travel distance. These distributions were then used to distribute the total quantity assigned to trucks between a given origin and destination among both types of lorries.

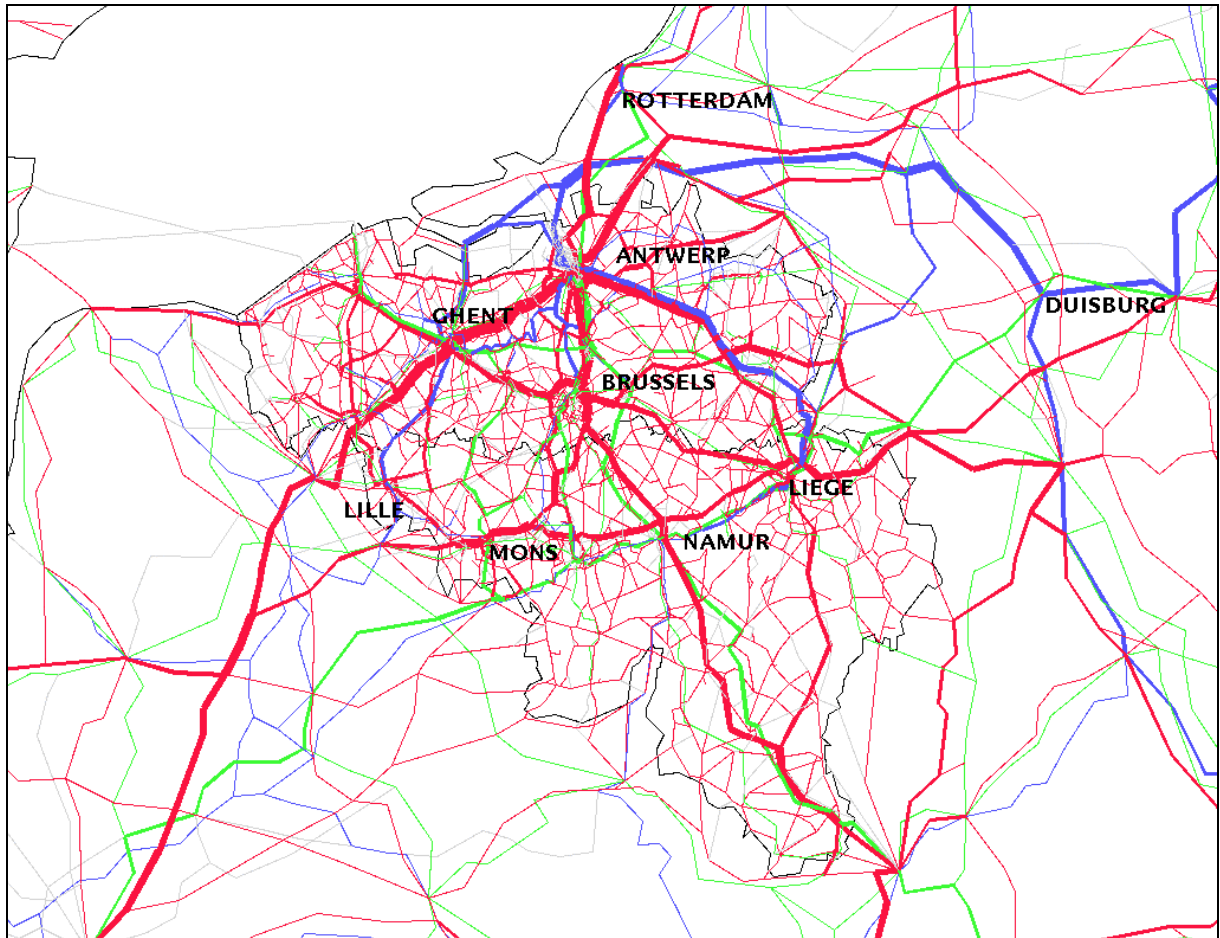
3.3 Validation of the reference scenario

Section 3.2 outlined the characteristics of the network model that was used and the way the model was calibrated. Table 1 gives a good idea of the performance of the model in terms of estimated market shares expressed in transported tons. The assignments on the most important links were also compared with the observed flows (counts). Correlation factors (r) of 0.91, 0.86 and 0.93 were respectively obtained on the inland waterway, railway and road networks. Map 2 illustrates the assignment.

Table 1: Assignment performance (tons)

NST-R	Observed (1995)		Estimated	
	Water	Rail	Water	Rail
0-9	11.28%	8.99%	11.06%	9.05%
0	7.18%	2.24%	7.56%	1.67%
1	5.06%	2.44%	5.61%	2.13%
2	25.33%	43.51%	25.11%	43.81%
3	28.65%	6.23%	28.89%	9.08%
4	25.06%	49.07%	18.66%	50.24%
5	7.44%	26.22%	7.32%	26.77%
6	15.37%	1.74%	15.44%	1.33%
7	23.70%	5.25%	24.09%	5.39%
8	8.00%	6.56%	7.85%	6.05%
9	0.53%	11.40%	0.88%	11.35%

Map 2: Reference scenario



4 The 2010 model

After the work described in section 3 was completed, a detailed reference scenario was made available, that could be used as a starting point to build up the actual transportation plan.

The first question that needs an answer at this point is : “What would happen if no new decisions are taken?”. In order to be able to estimate the flows on the network in 2010, both the demand (the O-D matrixes) and the supply (the transport infrastructures) must be “updated”.

4.1 Expected demand

As specified in section 3.1, the National Planning Office publishes projected figures for expected changes in the production and consumption patterns. These figures were used in the macro-economic model in order to appraise, per category of commodity, the impact of the economic activity on loaded and unloaded quantities per “arrondissement”. In average, the annual change in unloaded tons is about 2.40%. An average annual increase of 1.95% is expected for loading. The difference between these two figures can obviously be explained by the nature of the Belgian industry, which produces goods with a high added value, using a lot of raw material and energy.

As no precise information was available, the projections for transit flows was based on the observation of these flows between 1982 and 1995. The results of regressions done on these observations, per NST-R group of commodities, were used to modify the matrixes of the reference scenario.

All this put together, a new matrix could be build for each NST-R group for 2010. These matrixes are completely compatible with those used for 1995, i.e., the same O-D pairs are present in both sets of matrixes.

4.2 New transport infrastructures and flow assignment

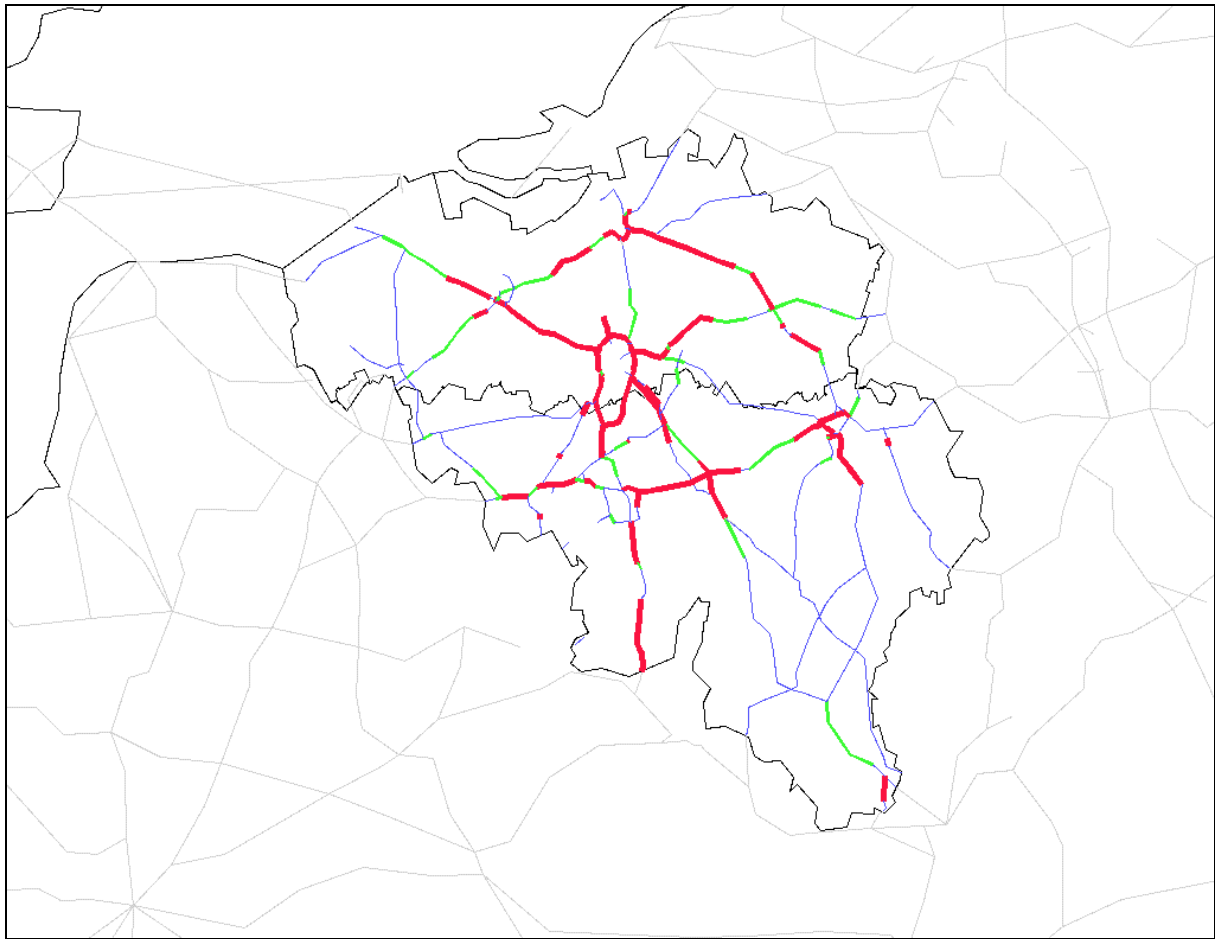
As a number of new infrastructures are already decided and will be available in 2010, the network must be updated, both in Belgium and in the surrounding regions. Some new highways will appear, some roads will be broadened, an important new lock will be created, some tracks will be electrified,...

As this 2010 scenario must be considered as an “unchanged” situation, nothing will be changed in the cost functions, to maintain the same relative weight between the use of the alternative transportation modes.

When the assignment of the new O-D matrixes on the “updated” network are compared with the results of the reference scenario, it comes out that the modal-split remains quite stable as the market share of road transport is only reduced by one percent. In other words, as the total quantity to be transported is increased by 40%, severe congestion problems may appear during peak hours. This is illustrated by Map 3, in which the red lines represents the roads on which the estimated assigned flow during the peak³ hours exceeds the standard capacity of the link. Green lines indicate a flow at least equal to 80% of the capacity.

³ The well known method of the 30th peak hour was used to estimate the flows during peak hours. It's also worthwhile to note that the previously discussed matrix of private cars was also assigned on the network so that the estimated flow contains both cars and trucks.

Map 3: Expected congestion points



5 Building alternative scenarios

Section 4 indicates that, if no new decision is taken before 2010, the road network would be much more congested than in 1995. It seems worthwhile to consider a set of alternative solutions in order to assess their impact on the entire network. Three of these scenarios are directly related to some changes in the transport conditions for a given mode, a last one tries to measure the impact of some cost internalisations.

5.1 Road

In this first scenario, several new or improved roads are introduced. The list of these investments was gathered through all kinds of studies that were done during the last years in Belgium and its border regions. The definitive list was discussed (and approved) with officials at the M.E.T. and representatives of other ministries. The results of the scenario were compared to the initial 2010 scenario: the modal split was hardly modified, but more truck transports use highways and assimilated roads. This is an expected result as most of the newly integrated investments are related to the creation of highways or the broadening of existing roads; as a result, a greater proportion of the road network belongs to the highways.

5.2 Water

As it was the case for the “road” scenario, a list of investments was discussed and approved by officials. In addition to new infrastructures (a new lock, the broadening of an existent canal, ...), navigation was also allowed on Sundays in this scenario⁴. This scenario has an impact on the modal split as transport by barges increases by 11% in Wallonia as compared to the basic 2010 estimation.

5.3 Rail

Beside the re-opening of a closed track and the creation of the “Iron Rhine”, this scenario also tries to measure the impact of the opening of a “freeway” in Belgium and the creation of a big industrial park that has logistic-oriented activities. This involves a substantial modification of the O-D matrixes, because some industrial activities are relocated at this new location. This work was based on a previous one done by Geerts and Duchâteau (1997).

The freeway was modelled as an additional transportation means with a commercial speed of 50 km/h, that only stops at some selected railway stations: Antwerp (B), Muizen (B), Bettembourg (L), Lyon (F), Torino (I). The new industrial park is also linked to the freeway.

The results of the output of this scenario was discussed with the national railway company in order to compare the needed capacity with the available one on the network.

This scenario increases the tonnage transported by trains by 13% in Wallonia, which represents a reduction of 2% of the road market share.

5.4 Internalisation of external costs

The three previously discussed scenarios give interesting results, but none has an important effect on the modal shift: in the best case, a reduction of 2% the tonnage transported by road can be expected, and that is not enough to reduce the level of congestion. An improvement of the networks and transport conditions doesn't seem to be sufficient to influence substantively the modal-split.

Alternative political decision can be taken, one of them is the internalisation of the external costs induced by the transport system. It is clear that such a sensitive political decision cannot be taken by the Walloon Government alone, but must be considered in the European context. Nevertheless, it is at least worthwhile to estimate the impact of such a policy.

Obviously, this research was not intended to estimate the value of the different commonly cited external costs such as congestion, emission of pollutants, accidents, noise and road damages, so that recently published values by De Borger and Proost (1997) were used. Two different scenarios were achieved. In the first one, all the external costs were internalised. In a second one, inspired by work published by the Economic and Statistic Office of the French Ministry for Infrastructures and Transport (SES 1997), these costs were only partially internalised. The different values that were used can be found in Table 2.

These scenarios have a much greater impact on the modal split. For instance, for a total internalisation, the market share (tons) in Wallonia for road transport is reduced by 10%,

⁴ This was simulated by a reduction of the transport costs by barges.

which correspond to an increase of 7% of rail transport and a gain of 3% for the inland waterways. This is very well illustrated by Map 1, in which plain lines represent increases of traffic and dashed lines a traffic reduction. It can easily be observed that the inland waterways and railway transport benefit from the cost internalisation.

Table 2: Levels of cost increases

	Increase of transportation cost	
Mode	Total internalisation	Partial internalisation
Road	40%	15%
Water	20%	10%
Rail	18%	8%

Such a result must be taken with some caution, like the results of the other scenarios, since the model remains “static” in the sense that there is no feedback on the demand. All the assignments are made with fixed demand, as if the demand was perfectly inelastic. If this can be rather easily accepted for the “infrastructure” scenarios which have only a very limited impact on transportation costs, things are not so clear for internalisation. Indeed, such a policy implies important changes of cost levels, which must have a negative impact on the total demand.

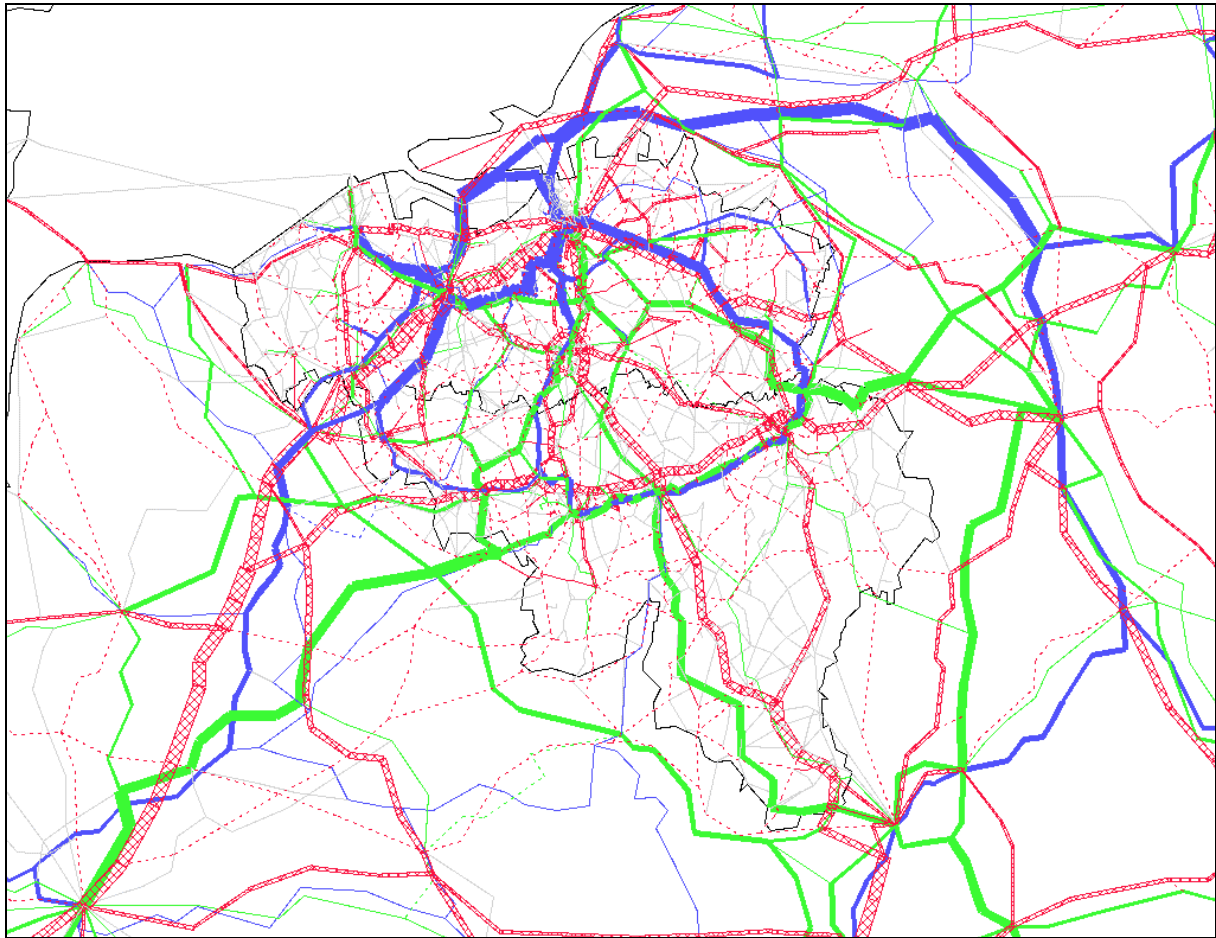
6 Final transport plan and sensitivity analysis

The different scenarios proposed in section 5 give a rather large palette of possible measures and decisions that can be taken by the Ministry. All the results that were obtained are obviously not published here, but there were enough details given to the Walloon authorities to enable them to “build” a transportation plan, i.e., made of elements from the different scenarios. The final choice included a partial internalisation of the external costs next to some additional infrastructures.

This final scenario was then compared to the basic 2010 situation. Moreover, low and high economic conjunctures were simulated through changes in the O-D matrixes.

All kinds of indicators can be computed on the basis of the results obtained, among which some kind of accessibility indicators calculated from the average cost per kilometre and the average speed on the network. So, if compared with the basic 2010 scenario, the average transportation cost in the final plan is increased by 10% and the average speed diminishes by 3 km/h (-8%). This is obviously linked to the fact that the plan includes a partial cost internalisation and that this internalisation implies a higher usage of slow transportation modes (rail and water).

Map 4: Impact of a total internalisation of external costs



7 Conclusions

This paper has presented some details of a research done by STRATEC, F.U.Ca.M.-G.T.M. and A.D.E for the Walloon Ministry of Infrastructures and Transport. The objective of the study was to correctly model the actual flows of freight transport through Wallonia and to analyse the impact of different infrastructure or policy oriented decisions on these flows in order to build a freight transportation plan for the year 2010. In addition to this work, a complete software tool was installed at the Ministry so that the Officials can build and analyse further scenarios.

Important data gathering made it possible to build detailed origin-destinations matrixes for the 10 main NST-R categories of commodities. The European network was also digitised at a rather detailed level. Belgium was even more detailed. Finally, complete cost functions were set-up for the different transportation means and operations.

For the network model, the methodology embedded in the NODUS software was used. It makes it possible to build transport models allowing complete and detailed analyses of multimodal freight transportation networks including intermodal solutions. It is based on the concept of "virtual network" which is applied in a systematic way to model all transport operations: travelling, (un)loading, transshipping, waiting, handling, paying tolls, etc. with

several modes and means of transportation. This methodology permits to solve the assignment and modal choice problems in one single step.

The output of the different scenarios was thoroughly analysed and the most promising elements of each of them were bundled into a final transportation plan, which robustness was finally tested among high and low levels of economic activities.

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