THE EFFECTIVE INTEGRATION OF LOGISTIC M&S IN INTERNATIONAL MULTILATERAL DEVELOPMENT PROJECTS: CASE STUDIES

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ABSTRACT
New transport infrastructures and services are always major investments subject to large uncertainty in its future. So the tools that can support the definition of its development and future operation have great importance. This paper presents the methodological definition and the first steps in developing two different models for a case study in Bolivia and in Brazil. The case in Bolivia is concerned with the development of a new stretch of railway that completes the Central Bi-oceanic Railway Corridor (CFBC). The case in Brazil deals with the analysis of transport capacity requirements for the Northeast Region. A combined methodology of transportation modelling and simulation is used in both cases, because it makes it possible the conducting of "what if" analysis, which will assess the transport service under different scenarios.

Keywords: Modelling and simulation, transportation model, mode choice, multimodal transport.

1. MODELLING METHODOLOGY

Due to the complexity of transport systems, planning is usually carried out adopting a hierarchical process (Bussieck et al. 1997). This process begins with the definition of the network and finishes with the definition of all the characteristics of the transport modes.

There are a wide range of available methodologies for transportation problems and to conduct the economic assessment of a new infrastructure or service. Most of these approaches follow similar steps in their development (Horn 2003). First, it is necessary to locate the points of origin and destination of all possible freight flows. Also, all the possible transport modes that the freight may employ need to be identified and, for each one of them, the cost and time incurred when using them. Cost and time are generally regarded as the two main factors determining mode choice, although safety and reliability measures could be taken into account. When it comes to multimodal transport, as this case is, it is also necessary to locate and identify modal interchange terminals, such as ports and rail terminals.

The methodology followed in these two case studies is based in the classical four stages model which is widely used in transportation planning (Ortúzar and Willumsen 2011). The four steps may be summarized as follows:

- Freight generation. Determines the tons of cargo generated in each traffic analysis zone (TAZ) by type of goods.
- Freight distribution. Determines the destination origin corresponding to each load, resulting in a set of origin destination matrices (matrices OD) expressed in quantity of material. Transformation to travel load (ie number of items and quantities) can be resolved at this point or the next.
- Modal Choice. Mode choice is modelled. In this project the available modes span road, rail, waterway and maritime.
- Assignment to the network. This step evaluates the network stretches employed per trip and therefore allows for assessing their total load.

OD matrices can be obtained directly from a single initial step in which either by surveying or historical analysis a representative set of origin-destination flows can be sampled. In the case where the source destination pairs are clearly defined (as befits a significant percentage of the goods of this study), surveying methods allow specific information on the types of units transported and thus avoids more aggregated and less accurate approaches.

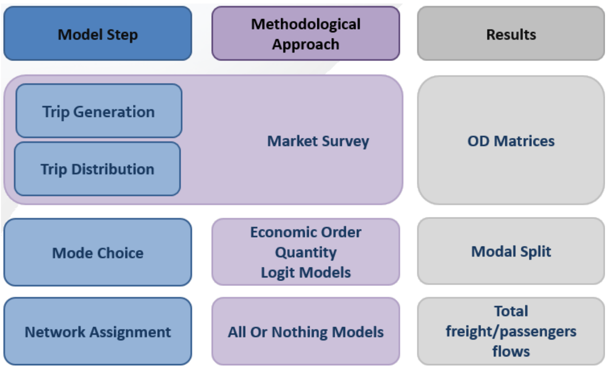

Figure 1: Methodology Diagram

This general analysis framework needs to be adapted to the specific objectives of the study. The extended methodology (based on the work of Holguín-Veras, 2002) that is used is described in the Figure 1.

2. THE BOLIVIAN CASE STUDY

On January 25, 2009 Bolivia approves State Constitution. It declared the country as a unitary multinational legal social, community, free, independent, sovereign, democratic, intercultural, decentralized and with autonomous regions. This new vision of the state establishes a development plan organized into five different actions. The actions on the transport are a key part of that plan. What is sought is the inner strengthening of state and relations with neighbouring countries, trying to eradicate inequality and poverty.

As a result of these initiatives the CFBC project (Central Bi-Oceanic Corridor rail) arises. The corridor will link the Atlantic and Pacific coasts of the central part of South America, reducing both costs and time of transporting cargo and passengers.

Part of the project is the analysis of Prospective Trade, Market and logistics alternatives. It seeks to determine the levels of demand for passenger and freight, the level of investment, traffic to and from Bolivia, Brazil and Peru, directly involved in the CFBC, but also Argentina, Paraguay and Uruguay through south rail links and the Paraguay-Parana Waterway. This study should also include intra-regional trade and with other continents.

This study has three main goals. First one is a prospective analysis of freight and passenger transportation, in different geographic (worldwide, national, regional) and temporal frameworks (long and short term). To make this analysis, simulation software is employed to assess different scenarios, of freight and passenger transportation flows, is required. Second goal is a market study, establishing demand levels, transport service characteristics, competition, commercial strategic etc. Last objective is the study of logistic alternatives in order to obtain multimodal options (where the CFBC is one of the stretches) that generate synergies and increase the competitiveness of the Bolivian Integrated Transport System.

This part of the project will be developed by a consortium of companies with the support of the Integrated Group for Engineering Research (GII).

The next sections show the steps following to define the better methodology to develop the project and its explanation.

2.1. Framework of the project

In 2010 South American countries promoted the Initiative for the Integration of Regional Infrastructure in South America (IIRSA). It aims at the planning and development of projects for the improvement of regional infrastructure in transport, energy and telecommunications. In Figure 2 we can see the Integration and Development axes. The infrastructure requirements are defined for each one in order to connect the territory with other parts of the region, planning the investments and increasing the quality of life of its inhabitants. The work presented in this paper belongs to one of the projects of the interoceanic central axis.

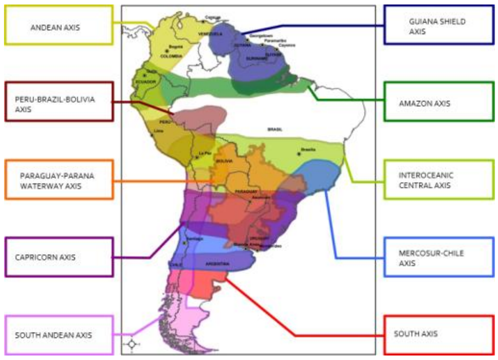

Figure 2: IIRSA axes.

For each axis, a set of project packages is defined that seeks to achieve improvements concerning various aspects. One of packages is concerned with the improvement of the connections between Bolivia and the ports in the pacific coast. Its objectives are:

- To increase the trade between the countries and to international markets.
- To reduce transportation costs to the Pacific Axis.
- To reduce import and export costs from the Pacific
- To increase synergy between the project groups.
- To increase reliability and raise transport sector standards.
- To promote the development and strengthening of border trade.
- To provide a physical connection to the MERCOSUR

In particular, in this package, the Central Bi-Oceanic Railway Corridor project (CFBC) is developed for which this work is being carried out.

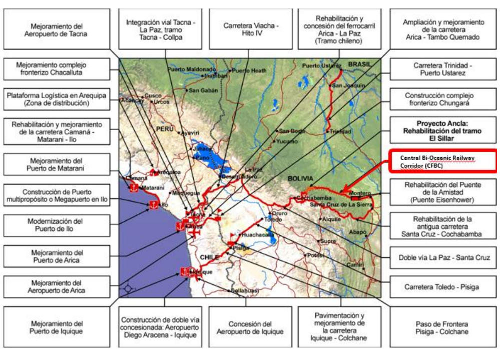

Figure 3: CFBC.

This corridor will allow the connection between the countries of the central zone of South America making possible the trade between them and the exportation to overseas countries. It is a railway corridor from Santos port in the Atlantic coast of Brazil to Arica port in Chile.

In Bolivia there are two railway nets, first one in the eastern zone and the other one in the Andean zone, but there is not connection between them in the central zone of the country as of nowadays.

This non-existent link represents six per cent of the total central corridor, around five hundred kilometres. Because of this, it is not possible a continuous traffic and the road links are not capable of efficiently supporting freight and passengers projections. So the IIRSA proposes some investments in order to improve the existing infrastructures and also to build the non-existent railway link taking into account technical, operational, environmental, economic and social aspects

2.2. The case of Bolivia

The road network of Bolivia has around seventy thousand kilometres, where ten thousand of them are paved roads. There are three types of roads: fundamental, complementary and local. There are around sixteen thousand kilometres of fundamental roads used for the international traffics and the main interregional traffic flows in Bolivia. In this moment there are a great number of projects to improve the roads of the country.

There are some roads that need to be improved and also new roads needed, which are included in the framework of the IIRSA projects. An example of the importance of any kind of initiatives is the road that connects La Paz with the Amazon rainforest region. It is a very dangerous road with a great slope and many accidents.

Figure 4: Example of Bolivian roads (Source: Agencia Boliviana de Carreteras).

The railroad network is divided in two systems. Both belong to the government but they are managed by two different companies, "FERROVIARIA ANDINA S.A." (FCA S.A.) in the plateau zone and "FERROVIARIA ORIENTAL S.A." (FOSA) in the eastern zone.

These lines have metre gauge like Brazil, Argentina and North of Chile, but not like Peru, which has a narrower gauge and Paraguay which has a larger gauge. In last years this transport mode has had low investment so the regional traffic flows are not significant. Its importance in the international flows is a little bit higher, in particular due to the mineral exports that take advantage of the economies of scale. This transport mode has a great potential, due to its lacking development.

The waterway network is formed by a set of rivers and lakes of the Amazon, and also by a connection with the Paraguay-Paraná waterway via Suarez Port. And it also has a set of airports, some of them international.

All of this shows the necessity to improve the transportation system in order to increase the competitiveness of the country and to help it to accelerate its development.

2.3. Steps of the project.

In order to obtain the desired results, the development of the project has to follow some steps. First one is a Market Survey to obtain all the necessary data to build the Transport model, second step is to build the model, and last step is the analysis of the results.

2.3.1. Market Survey.

Market studies provide information necessary for building the model, and for its validation. This raises the need for collecting relevant information as complete as possible, since it will determine the robustness of the model.

In this case there is a core group of goods from which is necessary to obtain as much information as possible. They are iron ore, soybeans and forest products since they are the main exports from Bolivia. Another fundamental transport should be taken into account is the passenger, whose data come from mobility surveys.

2.3.2. Transportation Planning Model

The central decision problem that will determine the competitiveness of the CFBC in relation to other transportation alternatives is a modal choice problem. The key feature of the model must be the ability to determine the allocation of freight flows between CFBC and all transportation alternatives considered.

This modal choice is determined by the interaction between the two main actors who make decisions: cargo shippers and carriers (Samuelson 1977, Holguín-Veras 2002). The shippers determine what freight will mainly be transported, to which destinations, in what quantities and how often. The carrier may determine the characteristics of the transport system, the level of services and set freight rates. In competitive market conditions, the interaction between the two will jointly determine the service characteristics and actual freight flows. Shippers have influence on carriers' decisions about transport settings, because they determine the characteristics of shipments of goods, and in turn carriers have influence on freight size chosen by the shippers and their modal choice, changing their pricing policies or by determination of a service level. This interaction can be modelled as a cooperative game in which previous research results (Jose Holguín-Veras et al. 2009) show that it can be assumed with a high degree of confidence that the decision finally adopted corresponds to the one that minimizes the total shipping costs , taking into account carriers and shippers.

So the total amounts of cargo being transported between each source-destination pair is determined by economic activity, the criteria determining modal choice by the shipper are directly related to business logistics. Taking this into account, trip generation does not have to be a linear relationship with freight quantity (in weight, it means in physical units) (José Holguín-Veras et al. 2011). The criterion applied by the freight shipping companies is based on the concept of Economic Order Quantity, which takes into account the relationship between inventory costs incurred by the company to consolidate orders and shipping costs to send that company assumes in shipping, and that are reduced by applying economies of scale in large orders.

So to solve the problem we have chosen the classical transport model of the four stages, but with variations to take into account the previous remarks.

2.4. Model implementation

The implementation of the model is developed in TransCAD, a transportation planning software that integrates a GIS.

Some macros are being developed, to implement all the steps of the transportation model. The following figure shows the model in the Bolivian area.

Figure 5: Model of Bolivia.

This figure shows the transportation model of Bolivia, grey line is the road network, with all the fundamental roads. Brown one is the railroad network, the existing links and some options for the new infrastructure. The all area is divided in the TAZs considered for the model.

This geographical part and the macros allow us to make some analysis, which main goals are obtain the better option for the new infrastructure and after that obtain the better operational conditions of the service.

To assess it the model give us some results, some of them are:

- Freight flows, for each commodity and period of time, for each origin destination pair.
- Freight flows, for each commodity and period of time, for all the links of the network.
- Percentage of freight absorbed by the CFBC, taking into account the origin, the destination or the pair origin destination. For each period and each commodity.
- Short path in terms of minimum total cost.
- Short path in terms of minimum total time.
- Total transportation cost, between points for each freight or all of them.

All these results will make it possible the analysis and assessment of the profitability of the service and the occupation of the networks.

3. THE BRAZILIAN CASE

3.1. Introduction

Brazil is the largest country in both South America and the Latin American region. It is the world's fifth largest country, both by geographical area and by population. The Brazilian economy is the world's seventh largest by nominal GDP and the seventh largest by purchasing power parity, as of 2012.

During the last years, Brazil has shown one of the world's fastest growing major economies, and its economic reforms have given the country new international recognition and influence. However, further efforts are required in order to reduce the socio-economical inequalities between Brazilian regions. At present, Brazil is developing specific strategies for the economic and social enhancement of the five macro-regions of which it is composed, i.e., Northern, Northeast, Central-West, Southeast and Southern.

The Northeast (NE) is one of the poorest regions in the country. Despite its important economic growth in the recent years, the Northeast Region still shows an important economic heterogeneity exacerbated by a restricting lack of intra and inter-regional integration as well as a minimum connection with international markets. Moreover, as it is visibly depicted in Figure 6, the NE region has been excluded from the plans of investment in the Initiative for the Integration of Regional Infrastructure in South America (IIRSA). For the Brazilian national and regional authorities, it has become clear the necessity of supporting plans for the development of regional infrastructures aiming at increasing the production capacity of the companies in the Northeast region.

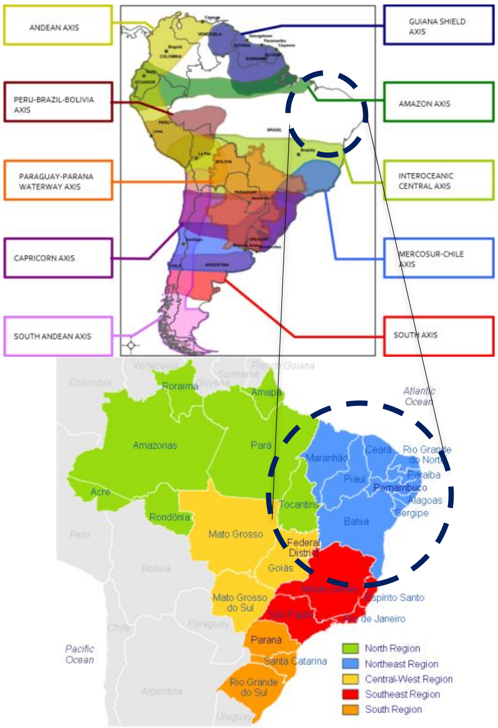

Figure 6: The Lack of Regional Consideration of the NE Region within the IIRSA, and Brazil Regions (in blue, the Northeast Region)

In this context of regional development strategy, the Banco do Nordeste de Brasil (Brazilian Northeast Bank, BNB) and the Inter-American Development Bank (IDB) agreed in 2012 the provision of financial and technical resources for structuring the Northeast Region Productive Development Programme (PRODEPRO). Its main objectives are the definition and proposal of new logistic and transportation infrastructures which will channel the present and forecasted production flows in order to improve the productivity and competitiveness of the NE companies –especially the SMEs- enhancing the physical integration between the nine states within the region and with the rest of the country; expanding the regional trade; and fostering the exportations and the attraction of foreign investments. And all of this measured in human dimensions such as the increase of the employment and income distribution rates, the social inclusion and the eradication of poverty.

Accordingly, one of the preparatory key works for the launching of PRODEPRO is the Investments Master Plan (IMP). The IMP will make it possible the identification and the prioritized proposal of the infrastructures required for the further development of production flows according to the aforementioned strategic objectives.

The IMP entails a series of objectives:

1. Characterising production sectors within the NE Region and detecting their technical, financial, infrastructural, legal, environmental and institutional needs.
2. Estimating growing and economic contribution growth of the production flows for a time span of ten years
3. Identifying and prioritizing investment opportunities in infrastructures for the region's production units, including their logistic inter-dependencies.
4. Determining the conditions for the attraction of national and international funds based on the elaboration of a "performance evolution" matrix for the existing production chains.
5. Identifying and improving the capacity of the integrated production flows axis by means of new infrastructures elements for the national and international trade.
6. Developing an Executive Plan describing the investments proposals supporting the development of the production flows within the NE region and its hinterlad aimed at achieving the maximum physical and economic integration between States and Regions.
7. Estimating the necessary investments for each action included in the Investments Management Plan.

3.2. The Project. The Infrastructures Master Plan (IMP).

As it happens in the Bolivian CFBC case, we once again find the proposal of Modelling and Simulation approaches and tools –and more precisely Logistic Simulation- by Multi-lateral investment organisations (in both cases, the IDB) within their projects. Multilateral Development Projects funded by Multilateral Organisations -the World Bank, the IDB, the Asian Development Bank or the African Development Bank, amongst many others- are complex and risky projects due to the following characteristics:

- They are granted after a highly competitive international tender process for which companies have already developed an important effort regarding human and financial resources dedication.
- Their international nature, which requires the allocation of organisational and financial resources in situ during the execution of works, which implies an important effort for companies, especially for SMEs.
- These are consortium projects, usually involving between three and five different organisations from different countries, which makes it necessary coping with language and cultural differences as well as providing with an efficient communications management system.
- Development projects are by definition multidisciplinary projects; a wide range of scientific and technical disciplines –from Sociology and Economics, to Geology and

Botany- have to be efficiently managed within the project framework. Thus, different paces, insights, priorities and languages have to be properly managed for the achievement of the final goals.

- These are "real world" projects, i.e., the consortium accepts the responsibility of accomplishing a predefined and agreed set of measurable executed works. They have little to do with common R&D projects for which uncertainty and risk are cushioned by non-reimbursement funds. In addition, they are quite demanding in terms of time and cost – reduced budgets which require an exact management in order to obtain a minimum ROI; and very short execution time windows of a few months- as well as in scope and quality (e.g., failing to meeting quality terms in one single project may lead the company to be blacklisted, i. e., the prohibition of being eligible for several years in this and other Banks' bidding processes)

For the works regarding the IMP a joint venture made up by three companies was chosen. The consortium is made up by two Spanish engineering SMEs (Proyfe S.L. and Teirlog Ingenieria S.L.) and one local partner (ASTEP Engenharia Ltda.). Proyfe on its turn will enhance their modelling and simulation capacities by means of the support given by the Integrated Group for Engineering Research (GII) of the University of A Coruna (Spain), strengthening their lines cooperation within an agreed framework of Open Innovation. This is a clear piece of evidence of a successful win to win scheme in Research, Technological Development and Innovation (RTDI) transfer from the academia to a company.

3.3. The Conceptual Approach

Since 2006, the Brazilian Ministry of Transport has been executing their National Transport and Logistic Plan (PNLT). The PNLT establishes a series of strategic actions aimed at reversing the current Brazilian transportation matrix focused on the multimodal transfer as a means of achieving a balanced regional economic growth. The PNLT has analysed the main 110 products accounting for more than 90% of the Brazilian GDP.

In doing so, two main approaches have been employed, (i) macroeconomic forecasting models -the EFES, Economic Forecasting Equilibrium Model- and (ii) Multimodal Transport Simulation Models. As a result, information regarding the nature of goods being produced, transported, consumed and exported is obtained. As it has been explained for the Bolivian case, availability of accurate and up to date OD matrices is an essential input for the completion of the multimodal simulation. Also, the other key element for the construction of the transport simulation model is the disposal of both the actual and forecasted network infrastructures.

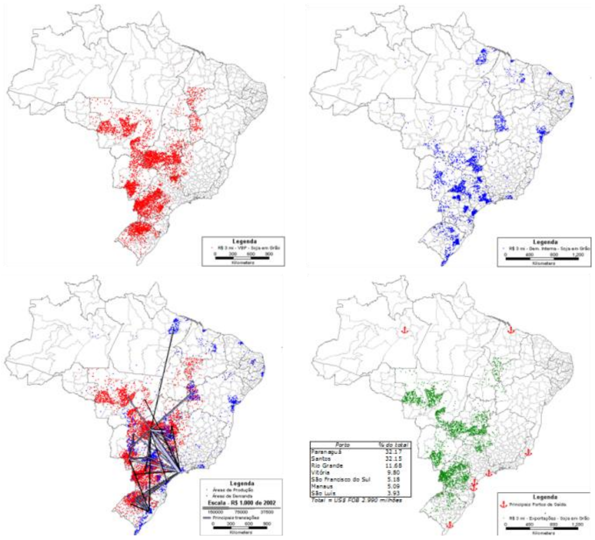

Figure 7: The characterisation of Soy Production (upper left), Consumption (upper right), Main inner flows (lower left) and Exportation Nodes (lower right).

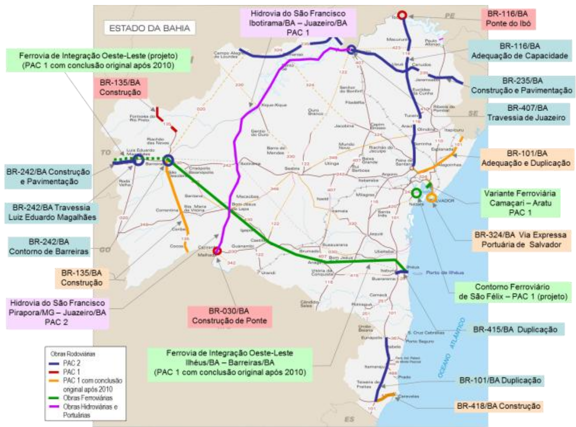

Figure 8: State of Bahia: an example of Regional Planned Infrastructures Development. Road, Rail and Waterway new or improved infrastructures have been programmed or in progress.

The PNLT will deploy resources and projects for the consolidation and improvement of the modal transfer from roads to maritime feeder and river way modes. As a matter of fact, between 1997 and 2010, the number of TEUs transported by rail increased by a factor of 71, whereas it did by a factor of 34 for the feeder maritime services. Also, in comparison with other similar countries –in terms of extension and logistic constraints- the Brazilian modal share displays a strong prevalence of the road mode (Figure 9) becoming the railway modal share a target to be improved (Figure 10).

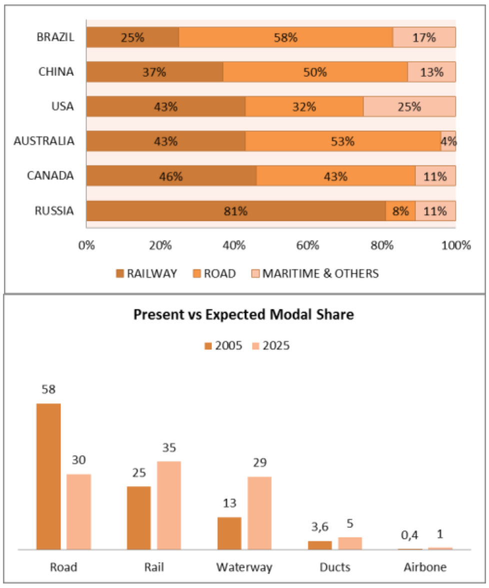

Figure 9: Brazilian Modal Split vs Similar Countries. Source: Brazilian Ministry of Transport

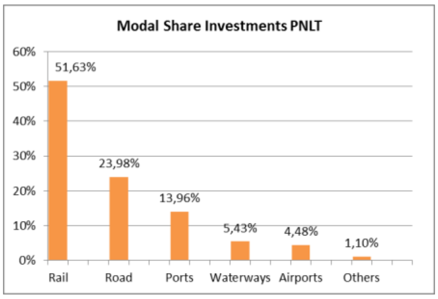

Figure 10: PNLT Investments for the Modal Transfer

Accordingly, our simulation model will first analyse the present capacity of the network in order to cope with the increase in production-consumption flows expected for the next 10-year period. An additional scenario will include the impact of the forecasted infrastructures in the modal split accounting for the percentage of freight absorbed by the targeted modes, i.e., rail, river and maritime feeder transport. The analysis of the results together with the joint consideration of other criteria regarding environmental strategic assessment and social aspects –amongst others- will lead to the proposal of a prioritised set of investments as the infrastructure pillar of the PRODEPRO programme.

4. CONCLUSIONS.

Transport infrastructure and services are key drivers of the economic growth in a region. However, planning activities are often challenged by the uncertainty in future conditions and the complexity of the studied transport networks. The two case studies presented in this paper are examples of these circumstances and how these problems can be faced in practice.

Both case studies also show the potential that M&S methodologies offer when applied in real case studies of transport planning and how they can contribute to improve the decision making processes in complex scenarios. One of the key features that M&S has to offer in practice is enabling the possibility of managing different scenarios in an efficient way. M&S is gaining momentum as a more and more common proposal by multilateral organisations when coping with the big uncertainties associated to big infrastructures projects, not only under the purely technical point of view, but also facing the managerial challenges of these sort of demanding projects.

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