A RANDOM UTILITY BASED MULTIREGIONAL INPUT-OUTPUT APPROACH TO ESTIMATE THE IMPACT OF A NEW HIGHWAY ON THE REGIONAL DISTRIBUTION OF JOBS

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ABSTRACT

This paper addresses the economic impact assessment of the construction of a new road on the regional distribution of jobs. The paper summarizes different existing model approaches considered to assess economic impacts through a literature review. Afterwards, we present the development of a comprehensive approach for analyzing the interaction of new transport infrastructure and the economic impact through an integrated model. This model has been applied to the construction of the motorway A-40 in Spain (497 Km.) which runs across three regions without passing though Madrid City. This may in turn lead to the relocation of labor and capital due to the improvement of accessibility of markets or inputs. The result suggests the existence of direct and indirect effects in other regions derived from the improvement of the transportation infrastructure, and confirms the relevance of road freight transport in some regions. We found that the changes in regional employment are substantial for some regions (increasing or decreasing jobs), but at the same time negligible in other regions. As a result, the approach provides broad guidance to national governments and other transport-related parties about the impacts of this transport policy.

Keywords: Economic Impact Assessment, New Road Assessment, Multiregional Input-Output Models, Integrated Economic Transport Model

INTRODUCTION

Transport is recognized as one of the crucial elements of economy since its costs are an essential part of total goods or service value. Moreover, transport is acknowledged as a derived demand since it is a key component of the activities that affect the economy in different ways. Nowadays policy makers face broad multifaceted alternative decisions regarding transport infrastructure construction, but the eventual use of assessment methodologies of alternatives enables them to establish key impacts.

The traditional transport policy assessment underlies in costs since they have different values in each different transport alternative. Indeed, these costs are categorized and incorporated in the decision-making processes of policy makers through economic analyses of benefits and impacts. These analyses assist effectively transportation decisions between different alternatives because they aim at a public objective rather than a particular dimension.

Transportation projects include different economic impacts (e.g. on the user, on the economy, and on the society (G. Weisbrod and B. Weisbrod 1997)), and different economic benefits (e.g. reduction of operating costs). In this sense, Alstadt and Weisbrod (2008) acknowledged that transportation project assessment is driven through economic impact analyses (as measured by employment, output, or income in the economy), and economic benefit studies (as calculated for Benefit/Cost studies). It is worth noting that transport project assessment has also been considered through Macro, Meso and Micro economic approaches (Organisation for Economic Cooperation and Development OECD et al. 2007).

In the macroeconomic approach, impacts on the economy are measured through changes in output and productivity in which the Aschauer methodology has been largely used (see for more details in Aschauer (1989)). This approach is focused on overall impacts by estimating effects on productivity of public capital in general, and of transport infrastructure in particular through either Keynesian or Neo-classic approach in national accounts such as, Gross Domestic Product (GDP), domestic consumption, or domestic employment used as a measure of welfare.

The microeconomic approach consist mainly of the Cost-Benefit Analysis (CBA). It is the largest popular *ex-ante* evaluation method used in transport. In fact, CBA has been used in planning and engineering studies for well over 50 years (Smalkoski 2003). CBA assessment is performed to determine the contribution on social welfare of society as a whole by considering the network impacts of such projects in travel times, safety, accessibility, reliability, and vehicle operating, maintenance and environmental costs (see for example, Bartin et al., (2011); Heyma and Oosterhaven (2005); De Rus (2008, 2011); and the Organisation for Economic Cooperation and Development OECD (2002))(Bartin et al. 2011; Heyma and Oosterhaven 2005; Organization for Economic Cooperation and Development OECD 2002; De Rus 2008, 2011).

Besides macroeconomic and microeconomic approaches, the mesoeconomic approach is considered as the level in which transport and other market interactions are explicitly (OECD,Organisation for Economic Cooperation and Development et al. 2007). Indeed, economic models like Input-Output (IO) accounting methods, and General Equilibrium

Simulation models, which describe consumption and production patterns and relations of economic sectors, represent that mesoeconomic level. Some of the successful applications of these models have been recognized in transportation and land use (see for more details Iacono et al.,(2008)).

This paper is organized into five sections. The introduction to the paper is developed in the first section. In the second section, the economic impact assessments of new transport infrastructure are reviewed. The third section describes the integrated model developed for assessing the construction of a new road. In section four we apply this model to the base-case scenario of Spain; afterwards, we introduce the description of the new road scenario for road freight transport in Spain considering the construction of motorway A-40. This scenario is assessed taking into account the benefits in the road transport network of Spain. Finally we analyze the results in terms of regional changes of jobs. The most relevant conclusions about the policy implementation, possible future developments, and limitations of the proposed approach are summarized in the last section.

ECONOMIC IMPACT ASSESSMENT OF NEW TRANSPORT INFRASTRUCTURE: A LITERATURE REVIEW

The economic impacts of new transport infrastructure have become an important issue for policy makers since there are multifaceted discussions about the contribution of infrastructure spending as a strategy to promote economic development (see Banister and Berechman (2001). For this reason various methodologies have been developed with different capabilities and strengths. The assortment of methodologies has been categorized based on their suitability to assess economic impacts in a number of different ways as previously mentioned.

The economic impact methodologies available for transport policies are diverse. Some of the remarkable methods regarding impacts of infrastructure spending have been developed under the Aschauer’s approach through production functions. However, several criticisms to this approach have been devised (see more details in Gramlich (1994); Holtz-Eakin and Schwartz (1995). Other different approaches have been developed using Vector Auto Regression (VAR) models or econometric approaches. For instance, Sturm et al., (1999) have found strong evidence between infrastructure investment and GDP in the Netherlands in the second half of the nineteenth century by using a VAR model. In addition, Chandra and Thompson (2000) have used an econometric model to assess the relation between new transport infrastructure and economic growth in the United States (US).

Other models have been developed relying in transport costs and travel times. These models consider changes in transport cost and times derived from certain policies as given directly; therefore the model estimates the effects on sectors’ activity, and on transport flow patterns. In fact, accessibility derived from changes in time or costs has been used in several economic impact assessments. For instance, a proposed 200 mile four-lane highway construction across North-Central Wisconsin in the US was accomplished by Weisbrod and Beckwith (1990) considering that the cost savings of the new infrastructure were provided as input into the economic model. In that analysis, five different alternatives were analyzed through an integrated model composed of a transportation model and an economic Input-Output model.

This study has evidenced the requirements of using separate models for an exhaustive economic assessment.

Other approaches developed for infrastructure improvements consider that economic sectors are subject to different impacts. Specifically Kanaroglou et al., (1998a; b) have developed a model based on the theory of multiplier analysis in which it was considered that there exist sectors that are highly dependent of transport as well as export oriented sectors that entail direct effects but also may trigger substantial indirect effects. The application of this approach to Ontario communities in Canada has predicted the impacts in terms of employment changes by sector.

At the European level several assessments have been performed for the Trans-European Network projects (TEN) under structural and cohesion fund investments. Some of the estimations are based on accessibility measures, which in turn enlarge accessibility of markets considering both intraregional and interregional access. This improvement has evidenced a relocation of labor and capital as part of the region's economic structure (see for example Rietveld and Nijkamp (1992); Vickerman (1995a; b); and Vickerman et al., (1999). Other analyses have been performed through Computable General Equilibrium (CGE) models such as the TRANS-TOOLS model, which is a decision support model for transport impact analysis. The economic impact assessment is performed through a multiregional CGE model of Europe. It is important to note that this is the most comprehensive model for the EU commission (Rich et al. 2009). The TRANS-TOOLS model has been developed since 2004 considering prior models such as SCENES, ASTRA, EXPEDITE, and TRENDS. This model has been largely applied to several EU projects (i.e. iTREN, WORLDNET, TENconnect ETISplus IBU-Öresund, and Baltic Transport Outlook), and to assess the development and redefinition of TEN projects as detailed in De Ceuster et al., (2005, 2010); Petersen et al., (2009). Furthermore, the TRANS-TOOLS model has supported the 2011 transport White Paper.

In Spain, the assessment of TEN projects has also been undertaken by the EU Commission. ECORYS (2006) has performed that analysis through a recursive-dynamic simulation model (SASI) of the assessment of possible projects of roads and rails to be developed in the period 2007-2013. The overall assessment performed in this study has evidenced economic impacts at regional level in terms of GDP per capita considering two scenarios of investment. The main driver of the assessment is the accessibility influenced by transport policy and investments. Also, this model has estimated the effects into neighboring countries.

Other assessment of Spain's infrastructure have been developed through the Aschauer's approach (see Baños et al. (2012), and Cantos et al. (2005)). Moreover, the availability of transport infrastructure among Spanish regions carried out by Herranz-Loncán (2006) has evidenced that the determinants of the distribution of infrastructure are largely adapted to the population density and the level of industrialization of each region. By contrast, the accessibility approach has been used by Holl (2007) to assess the motorways built in Spain. In this assessment, network access and market potential accessibility indicators were considered as for the road network in 1980 and 2000. These analyses evidenced the evolution of inequality indices such as, Coefficient of variation, Gini, and Theil.

As a result, the wide variety of currently existing models discussed above provides a good basis to estimate the economic impact of new transport infrastructure considering that the improvement of infrastructure may lead both distributive and generative effects. For this reason, a model would be designed in a way that can address these circumstances required by policy makers. Distributive effects describe the redistribution of economic activity among regions while the national total remains constant. By contrast, generative effects take place when the national total changes (considering a structure of regions).

Besides of macroeconomic, Computable General Equilibrium (CGE), and System Dynamics Models (SDM), one of the most suitable methods to assess economic impact of policies is the Input-Output model. This model has been commonly used to represent different economic systems (e.g. city, region, state or country), underlying in the concept that production of output requires input. This framework results highly convenient to represent transport flows since it captures accurately the essential mechanism that drives transport besides the conventional transportation demand models regularly used.

AN INTEGRATED APPROACH TO ASSESS THE INTRODUCTION OF A NEW ROAD

Background

Several economic assessments have demonstrated that the economic impact assessment of new transport infrastructure within the EU is performed through time and cost changes. (De Jong et al. 2004)Although extended integrated model approaches joining both the economic and the transportation system have been acknowledged, their adaptation to a particular policy situation in a country such as Spain is scarce. Moreover, the impacts on macroeconomic aggregates of transport policies at the regional level have hardly ever been studied because of the insufficiency of data and of suitable methodologies. However, several national models have been developed in Europe considering Input-Output economic relationships, Systems Dynamics Models (SDM), or Spatial Computable General Equilibrium (SCGE) models. (see more details in De Jong et al., (2004); NEA et al., (2010); Tavasszy (2006)).

These models address specific issues identified by Combes and Leurent (2007) in freight transport such as: 1) formation of scale economies; 2) integration of logistic stages along the transport chain; and 3) specificities of the spatial and technical structure of the industry and the requirements for trade. The model proposed for the assessment of a new motorway in Spain seeks to understand the spatial and economic relations, analyzing both output-supply and input-demand relationships through trade flow patterns among regions.

Our integrated approach recognizes that different types of industries are affected in different ways by specifying different impact mechanisms for either industries that are highly dependent of transport or export oriented economic sectors. For this reason, our modeling approach is based on combining two models that initially act as separate entities. We consider both the random utility-based multiregional Input-Output model approach (RUBMRIO), and a road network model. As a result, our model will predict different distributive impacts for regions with different economic structures.

This method is extremely useful to carry out an *ex-ante* evaluation of a new motorway for two main reasons. First, it captures accurately the underlying mechanism that drives road freight transport. Second, it determines regional substitution effects in countries, like Spain, where socio-demographic and economic attributes are different from region to region.

The Random Utility-Based Multiregional Input-Output Model (RUBMRIO)

The Input-Output (IO) framework has been a valuable tool for macroeconomic studies since it was first introduced by Leontief in the 1930s (Leontief 1986). The standard IO approach has been used in several economic analyses to estimate short-term effects of exogenous impacts (e.g., oil-price shocks, technological shocks, financial shocks, etc.). Extended IO models including other variables (i.e., social, and environmental costs) have estimated policy impacts derived from those variables.

Although the IO approach has been commonly applied to analyze the national economy considered as a homogeneous unit, it can also be applied to spatial scales that represent trade patterns between regions (ME&P - WSP et al. 2002). Multiregional IO Tables (MRIO) characterizes the economic relationship among the regions of a country (Duchin and Steenge 2007).

A MRIO table may be used to estimate macroeconomic impacts of transport policy measures through sector interdependencies and regional relationships expressed by means of both in trade and technical coefficients. Trade coefficients state the share of demand in a region satisfied by production in another region, while technical coefficients describe the input requirements per unit of production in a specific sector. MRIO tables address spatial patterns of economic activity location using demand functions for their spatial distribution (M Wegener 2004). This dependency may be pursued through the introduction of random utility-based models (RUBMRIO) to represent trade coefficients. Indeed, trade coefficients simulate the choice of supply region since they show the probability that a product of sector m destined to be consumed within the region j, will have been transported from the production region i.

Some researchers have included in the utility function rail and road transport through a Nested Logit model (NL) (see Kockelman and Huang (2007); Kockelman and Ruiz Juri (2004); Kockelman et al., (2003)), while others have considered regional differences by including a dummy border variable in order to better approximate reality in these models (see Marzano and Papola (2008).

RUBMRIO analysis has been performed in well-known land-use models involving spatial economy (e.g. MEPLAN, TRANUS, and PECAS (Echenique 2004)). This methodology has also been employed for transportation policy analysis to overcome the weakness of the typical travel demand modeling approach. Existing RUBMRIO applications of transport policy measures cover different *ex-ante* topics, such as: construction of corridors as part of new road infrastructure, changes in travel times, transport investments, operational cost variations, fuel taxes, trade pattern changes, and regional transport conditions (for more details see Cascetta and Di Gangi (1996); Cascetta et al., (2008); Di Ciommo et al., (2012); Kockelman and Du (2012); Kockelman and Huang (2007); Marzano and Papola (2008)). These applications have found important indirect effects of transport policies at the regional level on various macroeconomic aggregate indicators, such as employment and GDP. However, most of these applications do not include direct effects in the transportation system. The relationships of substitution and complementarity among different regional areas requiring transport services were traditionally assessed by considering prices of sectors' products due to changes to the infrastructure of a road transport network.

The RUBMRIO approach (**Figure 1.a**) describes through an IO framework the production and trade patterns of economic sectors which will respond to prices $\mathrm{p_i^m}$ based on a utility expression, $\mathrm{u_{ij}^m}$ for each sector m and region pairs i, j. The solution of the price is achieved through an iterative single fixed-point algorithm. This algorithm defines a sole spatial equilibrium solution. Main assumptions about the procedure are extensively described in Kockelman and Zhao (2004). Also, Kockelman and Huang (2007) have noticed congestion feedbacks by converting monetary flows into vehicle flows, and assigning these to the transport network to provide new travel times to update costs. It is worth noting that Marzano and Papola (2004, 2008) have proposed the RUBMRIO model solution through a double fixed-point formulation considering the introduction of a new feedback in the model. However, the conditions of allowing for a solution and uniqueness of the double fixed-point approach are still under development.

The algorithm considers the following steps: 1) utilities $\mathrm{u_{ij}^m}$ are computed (considering initial values of the purchasing prices p_i^m set to equal zero); 2) production X_i^m is evaluated by the flow of goods and services x_{ij}^m (considering initial values set to equal zero) and final demand, Y_i^m; 3) consumption C_j^m is calculated considering technical coefficients $a_j^{mn}$for the production process of all sectors across regions, and total production, X_j^n; 4) interregional flows, $X_{ij}^m$are distributed considering utility variations; 5) the tolerance criterion is evaluated. In the case of achievement the procedure stops, and these interregional flows are the inputs for the road network model (**Figure 1.b**). 6) if tolerance was not achieved, prices p_i^m are updated through acquisition costs, ac_j^m to represents the average weighted cost of commodity m in zone j; 7) new prices are computed considering technical coefficients without import considerations a_{0j}^{mn} as a proxy of the quantity of sector n needed for the production of one unit of sector m in the region j, q_j^{mn}. These new prices are used to run a new iteration until the equilibrium of interregional flows is achieved.

The Road Transport Network Model

The road network is made up of a set of nodes and links. Links represent the physical structure over which traffic stream moves including attributes, such as: length, travel time, speed, number of lanes, and traffic flow restrictions. As Filipov and Davidkov (2006) highlight, these elements provide an advanced model that can represent complex scenarios to model multimodal transportation networks, impedances, restrictions, and hierarchy for the network. The nodal 'points' have attributes such as the origin and end point of the roads, identification of regional capitals, larger municipalities or ports.

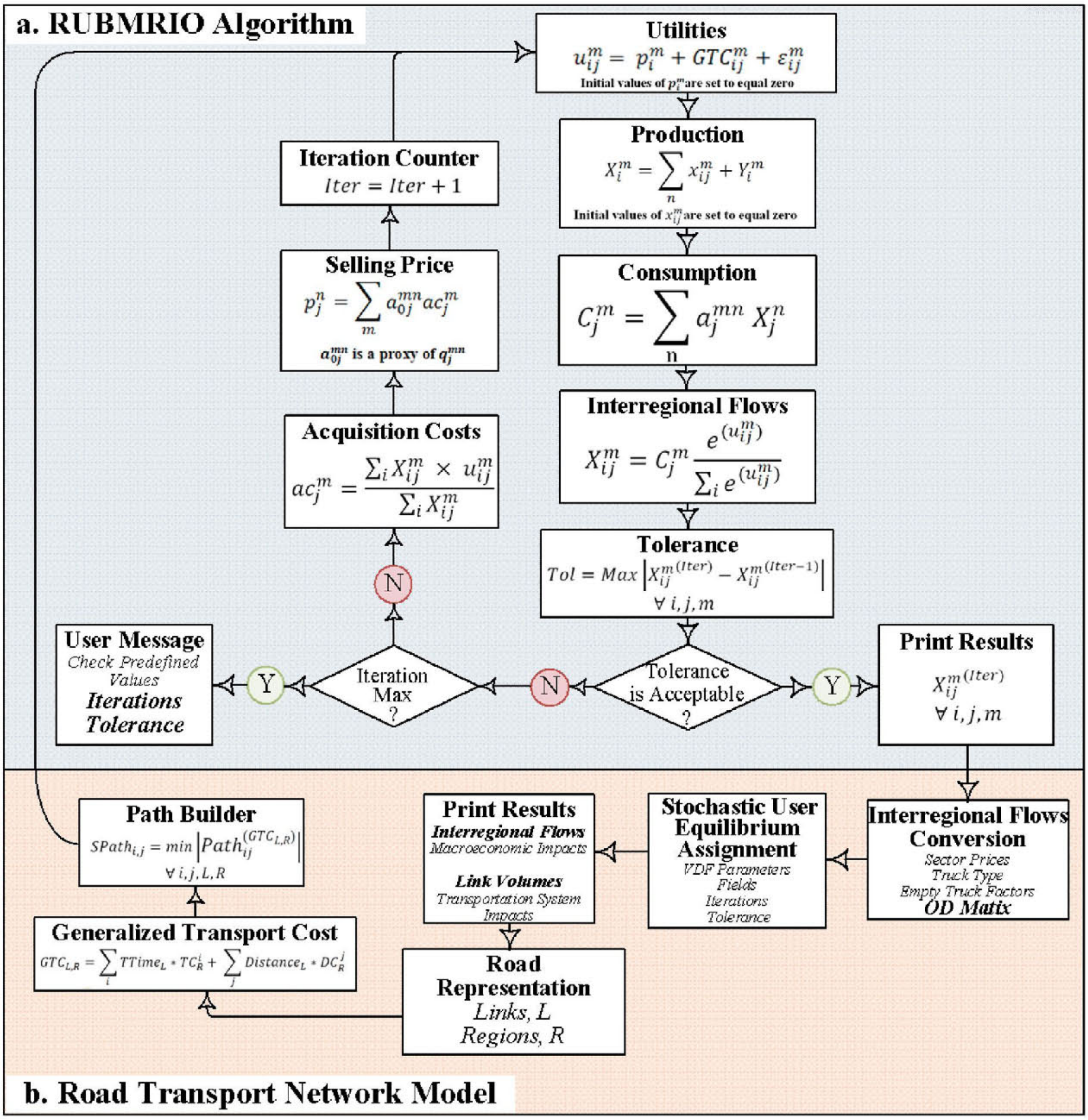

Figure 1 - An Integrated Approach for Assess the Introduction of a New Road

The model should deal with the spatial representation of transport flows on a road network considering an assignment procedure used to predict the traveler's choice of routes in the road transport network. In this case, the model considers the fact that link travel times are flow dependent. A volume-delay function (VDF) should be considered to reflect traffic behavior as is shown in equation (1). This traditional formulation was proposed by the Bureau of Public Roads (BPR) in 1964, and has been used since then, to specify how sensitive the network times are to traffic congestion.

$$T = T_o \times \left[1 + \alpha \left(\frac{v}{c} \right)^{\beta} \right] \qquad (1)$$

T is the travel time. T_0 is the free-flow travel time. v is the traffic volume. c is the practical capacity. Finally α, β are BPR parameters defined by link type (usually 0.15 and 4 correspondingly). These parameters facilitate the adoption of different functions for different kinds of links and for each class of traffic. The practical road capacity c is generally used to mean the maximum possible flow of vehicles that can be allowed in a road section per time period (usually one hour). However, this time period could also specify another situation (e.g., morning peak period, midday period, and the evening peak period). Normally, most travel demand models use time-of-day factors to distribute trips according to specific time periods to reflect the peak period traffic behavior (see, for example, the models of New York, Southeast Florida, and Indiana (CG 2008; Horowitz 2006; PB et al. 2005)).

As a result of the model assignment, a generalized transport function in each link is computed. Also, a shortest transport cost path builder, which defines the shortest route between any two locations through a minimization criterion (e.g., of length, time, cost, etc.) is executed. In the path builder, the route is selected if, and only if, the criterion of reaching the destination node (*D*) from an initial origin node (*O*) through links (*L*) of the transport network layer is the minimum.

Model Integration

From the road transport network, the shortest path cost routes among regions are computed to generate RUBMRIO input. Once the algorithm reaches equilibrium, the economic impacts are calculated. Afterwards, Origin-Destination (*OD*) matrices are created. These *OD* matrices for each economic sector are assigned to the road transport network to determine traffic volumes on the road network links that enable us to calculate transportation system impacts if wanted.

CONSTRUCTION OF THE MOTORWAY A-40 IN THE SPANISH ROAD TRANSPORT NETWORK

The Road Transport Network of Spain

Spanish road transport network has been promoted since the 1960s through different strategic national master plans for infrastructure. However, as Izquierdo (2004) recognizes, the transport infrastructure policy have changed significantly since 1996 after joining the European Union as a full member. It has been an important catalyst in the development of the transport infrastructure in Spain because the European Commission, (EC) have encouraged the development of TEN projects as part of the European integration with the assistance of European funds. In addition, the EC through the white paper for transport has given strategic orientation to the development of transport in the EU members.

Spain road transport network has witnessed the development of a vast motorway network in the past two decades. Nowadays Spain has the second largest highway network in Europe right behind Germany although other EU countries as Netherlands, Belgium have the densest network. In 2007, Spain registered a modern high-capacity road transportation network including tolled and motorways roads (see **Figure 2**). It is worth noting that the total high-capacity road network has been growing steadily from 8,893 Km (year 1999) to more than 13,000 Km (year 2007) (EUROSTAT 2011). According to information of the Ministry of Public Works - MFOM (2008) 9,790 kilometers of these roads are under control of the

National Spanish Government and the remaining kilometers depends on Autonomous Community Governments.

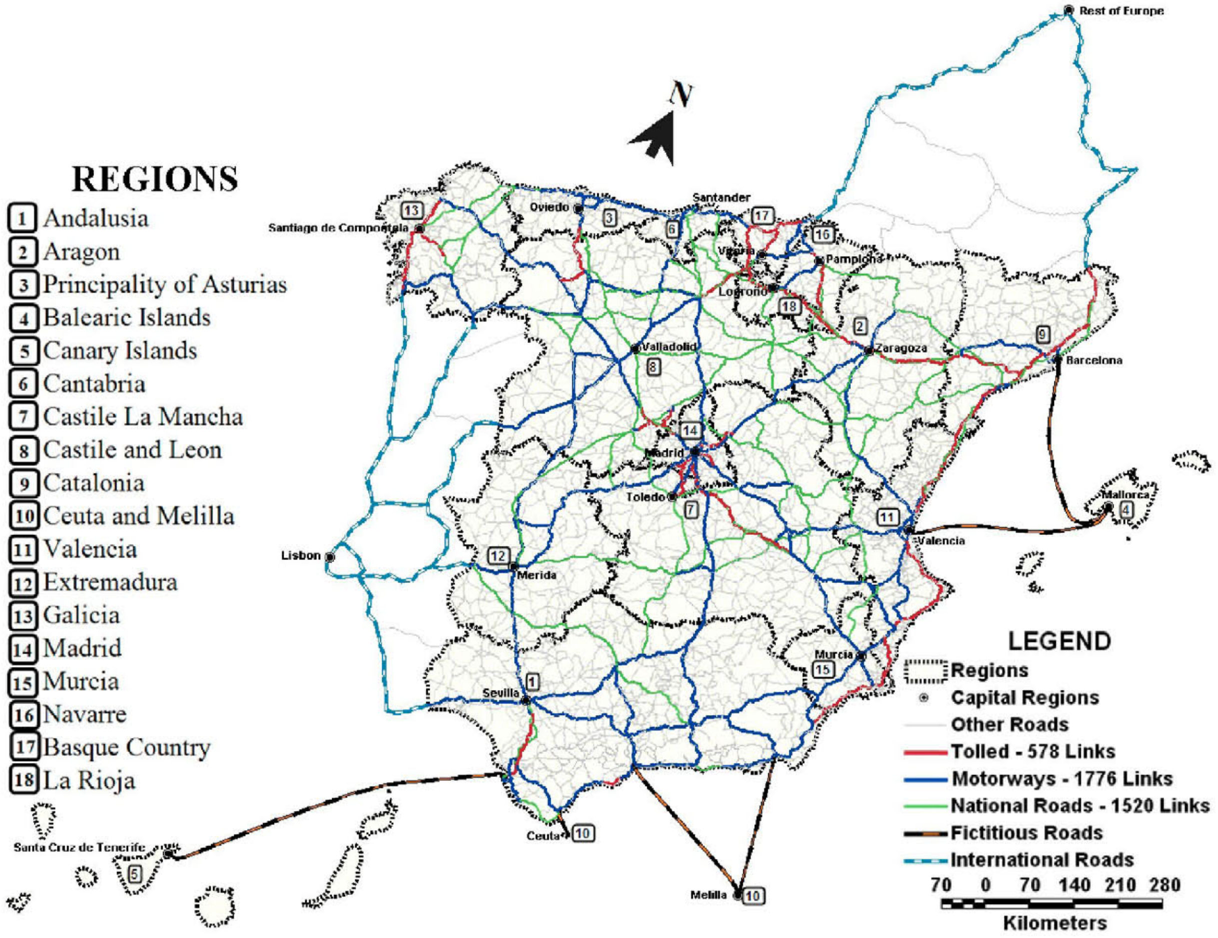

Figure 2 – Spain road transport Network (year 2007)

Base-Case Model Contribution

In this section we apply the model structure described in the previous section for the base-case scenario detailing the main components, assumptions and procedure used. This application considers the road transport network depicted in **Figure 2.** We consider only freight road transport through Heavy Good Vehicles (HGVs) since the motorway proposed in the scenario model will link interregional networks being more significant for freight. Moreover, the modeling approach selected is highly suitable for this kind of transport rather than for passenger cars.

The RUBMRIO Model

In order to build the model for Spain we used the existing interregional IO table for 2007 including 18 regions, and 26 sectors. This table was built for the DESTINO research project (Ministerio de Fomento - MFOM 2011a). A simplifying procedure was developed to aggregate sectors and to discard interregional relationships among sectors (*m* to *n*) to obtain a MRIO. The final number of sectors considered was 18, of which 9 were specially higher freight transport intensive (mainly, and mostly transporters of goods) according to the

National Freight Transport Survey (Ministerio de Fomento - MFOM 2007a), and 9 non-freight transport intensive sectors, as is shown in **Table 1**.

We adopted a NL model considering the choice of regions in two relevant nests (region and other), and four relevant alternatives (same, close, near and far) as presented in equation (2). This NL structure was a way of overcoming problems detected in the single level multinomial logit formulation. We did not include rail in the model because, its share in Spain is very low for domestic freight transportation (Vassallo and López 2010).

$$u_{ij}^{m} = -p_{i}^{m} + \lambda^{m} \ln\left[\sum_{R} exp(u_{ij,R}^{m})\right] \qquad (2)$$

$$u_{ij,R}^{m} = \beta^{m} GTC_{ij,R}^{m} \qquad (3)$$

u_{ij}^{m} represents the utility of acquiring commodity m in region *i* and transporting it to region *j*. The systematic utility of the lower nest $u_{ij,R}^{m}$ is defined in equation (3). p_{i}^{m} is the price of goods/services of sector m in region i. λ^{m} and β^{m} are logit model parameters, and GTC_{ij}^{m} is the generalized transport cost of sector m goods from production or origin region *i* to consumer region *j*. Total *GTC* between production and consumer regions was considered to avoid possible multicollinearity in each term of the cost function. For the calculation of transport costs inside the same region (i.e. *i=j*), an average cost was determined from the capital of the region to provinces of that region or interest points (ports, and large municipalities) using the road transport network, to facilitate the representation of intraregional costs.

The regions outside continental Spain (i.e., Canary Islands, Balearic Islands, and Ceuta-Melilla) were linked to the continental transport network using fictitious links, assuming a larger cost attribute in the transport network to diminish the possibility of freight road travel. The utility parameter calibration is shown in **Table 1**.

The NL utility model calibration parameters were obtained using the NLOGIT software considering the maximum likelihood method. The Wald statistical significance test (values are shown in parentheses) shows that some parameters achieve significance of 95% and others 90%. Also, the likelihood ratio test gave appropriate values for this model application. Low values in these two tests could be explained by the lack at this point of sufficient data, and point up the need for more data on goods transport flows in order to obtain more precise results, as indicated by Kockelman (2008).

The single fixed-point algorithm solution shown in **Figure 1.a** was adopted to achieve a solution for the RUBMRIO model. The tolerance was established as a value of 0.01, and was reached through the algorithm implemented using Excel VBA.

Table 1 Economic Sectors and Utility Parameter Calibration

SECTOR			β	λ	Likelihood ratio Index
FREIGHT TRANSPORT INTENSIVE	1	Agriculture, Fishing, Wood and Cork	-0.0036997 (-1.791)	0.6022334	0.1509
	2	Food and Kindred Products	-0.0022116 (-1.618)	0.3980369	0.1737
	3	Non-metal Minerals and Kindred Products	-0.0031048 (-2.469)	1.2123022	0.1738
	4	Energy, Petroleum and Petroleum Products	-0.00359032 (-1.662)	0.2856076	0.1012
	5	Mining	-0.00292221 (-2.393)	0.9987490	0.3280
	6	Metal minerals and Kindred Products	-0.00261765 (-1.942)	0.7592084	0.1227
	7	Construction	-0.00362973 (-2.508)	1.7298120	0.3650
	8	Chemical and Allied Products, Paper, Edition and Kindred Products, Rubber Materials	-0.00186099 (-1.726)	0.5344023	0.1664
	9	Textiles, Clothing, Leather and Shoes, Industrial Machinery and Equipment, Electric and Electronic Equipment, Transportation Equipment, and Other Manufacturing Industries	-0.00251822 (-1.68)	0.4169975	0.1436
NON-FREIGHT TRANSPORT INTENSIVE	10	Trade and Repairs of Vehicles			
	11	Tourism			
	12	Transportation, and Storage			
	13	Communications			
	14	Finance and Real Estate			
	15	Government Services			
	16	Education			
	17	Health			
	18	Other Non-government Services			

The Road Network Model

The Road Network

In **Figure 2** the 2007 road freight transportation network is depicted. The road network model was built in TransCAD. All inputs for network links were defined according to road functional classification class as shown in **Table 2**. Spain's road transport network for HGVs has 14,814 kilometers distributed in tolled, non-tolled, and national road. Furthermore, traffic count data was also included in each link considering passenger cars, buses, and HGVs classes. This data was taken from official statistics of the Ministry of Public Works – MFOM

(2007b) to be considered as preload traffic and to validate the base-case year assignment model.

Table 2. Road Transport Network Input Data

Functional Classification Class	**Cross Section**	**Speed (Km/h) Terrain**			**Capacity (P.C.U. per hour per lane) Terrain**			**Volume Delay Function parameters (VDF)**	
		L	**R**	**M**	**L**	**R**	**M**	α	β
1 Toll Highways	3x3	100	90	70	2,000	1,800	1,700	2.00	10
	2x2	100	90	70	2,000	1,800	1,700	2.00	10
2 Motorways	3x3	90	80	60	1,900	1,700	1,500	0.90	4
	2x2	90	80	60	1,900	1,700	1,500	0.90	4
3 National Road System	2x2	70	50	40	1,500	1,300	800	1.00	7

P.C.U. = Passenger Car Units
L = Level (0- 5%)
R = Rolling (5-15%)
M = Mountainous (>15%)

Interregional Flow Conversion

Conversion factors were applied to convert each economic sector trade from monetary units (Euros) to tons, tons to trucks per year, and these figures expressed as trucks per day. This conversion considered an average price per ton (€/tons), HGV configurations of each sector, since size and weight limits could vary (e.g. bulk, tank, refrigerated HGVs, among others), and a factor reflecting the percentage of empty trucks. The percentage of empty HGVs trucks was adopted from MFOM (2007a) considering loaded and empty operations as a proxy. Also, information regarding external trips (imports and exports to/from other peripheral countries as Portugal, and elsewhere in Europe) were adopted and incorporated from the research of Gutierrez et al., (2012), since it was not considered in the RUBMRIO.

The Assignment Model

A Stochastic User Equilibrium Assignment (SUE) procedure was selected to perform HGV traffic assignment. This procedure was chosen because it is frequently used for statewide travel demand models for freight and passenger transportation (Horowitz 2006). This procedure is also more realistic because it acknowledges individual variations in generalized cost perception. The SUE procedure makes it easier for haulers to choose alternative routes. According to this procedure less attractive routes will have lower utilization, but will not have zero flow. The optimal solution is achieved through an interactive Method of Successive Averages (MSA), given a convergence criterion.

The VDF function shown in equation (1) was adopted considering a time period of 24 hours (one day) since detailed information about time periods was not available. Daily capacity is assumed as the hourly capacity expanded by a daily expansion factor (Ye 2010).

Base-Case Calibration and Validation

As Parsons Brinckerhoff – PB et al., (2005) admits, the result and demonstration of the calibration is referred to as model validation. It starts with the most general aggregate verification and progresses towards more detailed volume-related verification (TMIP 2010). Generally, root mean square error (RMSE), percent RMSE (%RMSE), and total error are calculated and factored into the analysis. The validation was conducted on the basis of comparisons between predicted and observed flows on links for the base-case scenario considering changes of volume-delay function VDF parameters as well as daily expansion factors in an iterative process intended to minimize deviations between assigned and observed traffic flows.

The validation results depicted in **Table 3** shows how recommended targets in the guideline of the FHWA – TMIP (2010) were met by facility type, considering lower values (less than 30%) for higher volume roads (i.e. tolled and motorways). Higher values were registered on lower volume roads such as the national road system. However, these values do not exceed target recommendations given by the TMIP guideline. Consequently, the resultant model has a reasonable accuracy for the expected integrated approach.

Table 3. Model Validation by Functional Classification Classes

Functional Classification Class		Number of Links	Average Error *	% Error **	% RMSE ***
1	Toll Highways	578	-111.88	-3.65	29.92
2	Motorways	1776	129.39	3.57	21.91
3	National Road System	1520	183.50	19.86	45.55
ALL		**3874**	**114.62**	**4.62**	**27.95**

* $Average\ Error = (Estimated\ Volume - Count\ Volume)/Number\ of\ Links$

** $\%\ Error = ((Estimated\ Volume - Count\ Volume)/Count\ Volume) * 100$

*** $$\%RMSE = \frac{\left(\sum_i (Estimated\ Volume_i - Count\ Volume_i)^2/(Number\ of\ Links)\right)^{0.5} * 100}{\left(\sum_i Count\ Volume_i / Number\ of\ Links\right)}$$

Shortest Path Cost Builder

Links are characterized by time and length. In order to incorporate these variables in the decision making process, a Generalized Transport Cost (*GTC*) function was defined for each link considering its regional location according to equation (4). This linear function represents the total cost attributed to each link when it is reached.

$$GTC_{L,R} = \sum_i TTime_L * TC_R^i + \sum_j Distance_L * DC_R^j \qquad (4)$$

$GTC_{L,R}$ represents the generalized transport cost in each link (*L*) belonging to specific region (*R*); TC_R^i are time costs per minute, including labor, financing, insurance, tax, and other indirect costs. Distance costs DC_R^j in euro per kilometer include fuel, tolls, accommodation, allowances, tires, maintenance and repairing costs. The functionality is implemented in

TransCAD through the Multiple Shortest Path algorithm. The resulting shortest path network provides the GTC_{ij}^{m} to be used as a feedback in the approach as is shown in **Figure 1** above.

The Motorway A-40 Scenario Model

Background

Since the 1990s the motorway A-40 was proposed by the Ministry of Public Works to improve the connectivity of Castile La Mancha region (MFOM, 2011a). This motorway has 497 Km and will commence just in the motorway A-6 (Adanero) and terminate in the vicinity of the province Teruel (motorway A-23). It runs directly across Castile and Leon, Castile La Mancha and Aragon regions (see **Figure 3**). For this reason, this motorway is a strategic route for HGVs transport since it will be a backbone for Spain connecting East/West, North/South and vice versa paths of these regions to provide a direct connection with the Mediterranean without passing through Madrid City. However, this motorway has not been included in the TEN projects to receive funds because it does not connect the Iberian Peninsula with the rest of Europe.

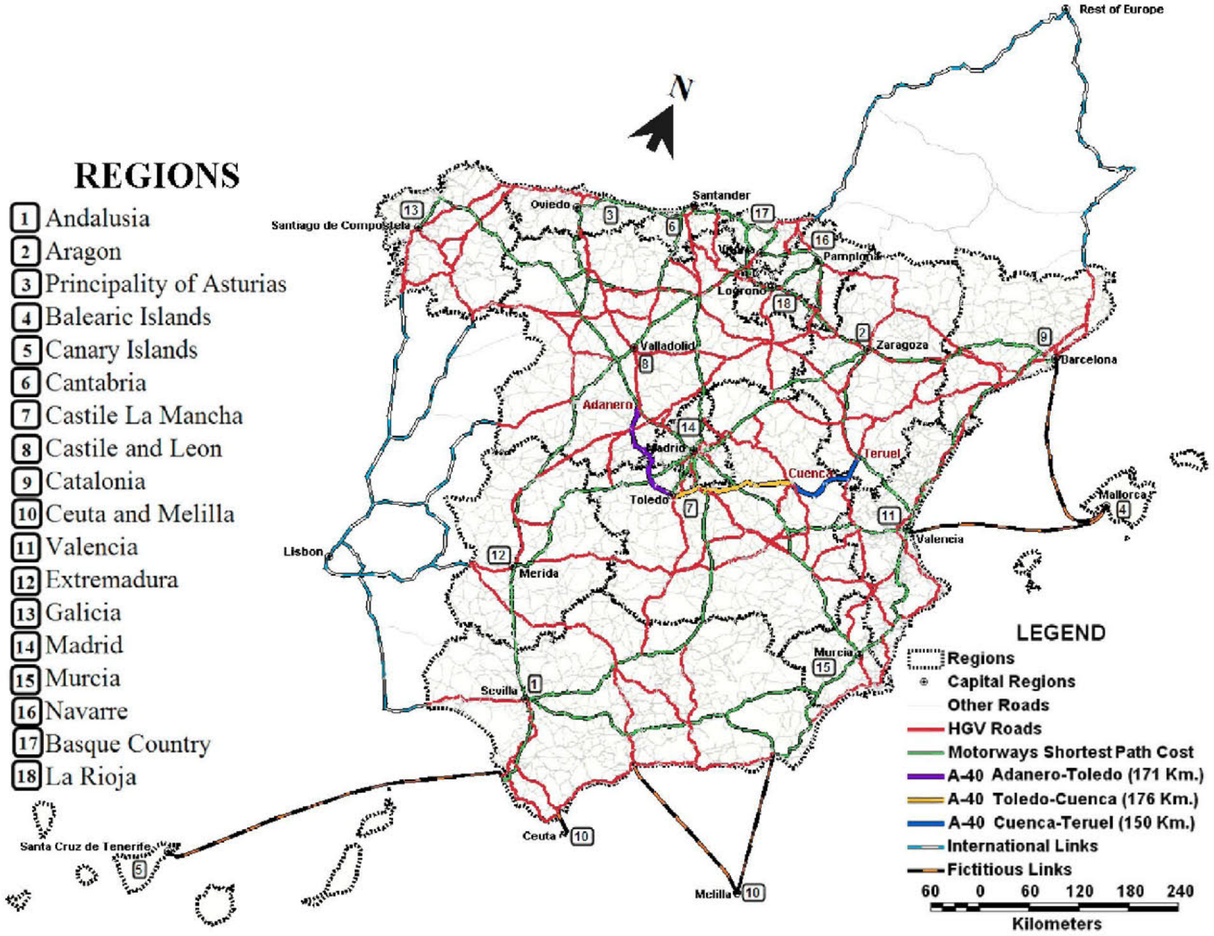

Figure 3 –Spanish Road Transport Network and Motorway A-40

This motorway has been gradually constructed and opened. The central part (Toledo – Cuenca) has been partially opened since 2004, and up to date has approximated 150 kilometers opened (Ministerio de Fomento - MFOM 2011b). The other remaining two segments are under feasibility studies for a later tendering process (see segments in **Figure 3**).

The Model Scenario

The construction of motorway A-40 will improve interregional and intraregional transport since existing facilities that supports trade among Spanish regions through HGVs vehicles will enhance its efficiency. We base our motorway A-40 model scenario comprising 3 different segments of existing national roads of the year 2007 (N-403, N-400, and N-420). In the model scenario, these roads are subject to improvements considering the modernization of the old roads.

Mainly, the improvements will bring it up to today's standards. Our model scenario includes rerouting of segments, construction of new roads and medians, partial reconstructions, rehabilitations, gradient changes, bridges, drainage facilities, and overlays. These major improvements will turn the existing single carriage in a dual carriageway which will provide a four-lane motorway. Moreover, estimated road construction and improvement costs of these three roads were not considered in our scenario since it is beyond the scope of this paper. In **Table 4** we summarize the existing conditions and the future conditions included in the model scenario.

Table 4. Motorway A-40 Model Scenario

Road Segment	**Old Characteristics**				**New Characteristics**			
	Length (Km)	**Speed[*] (Km/h)**	**Travel Time[**] (h.min)**	**Cross Section**	**Length (Km)**	**Speed[*] (Km/h)**	**Travel Time[**] (h.min)**	**Cross Section**
1 N-403 (Adanero – Toledo)	178	62	2.50	1x1	171	86	1.59	2x2
2 N-400 (Toledo – Cuenca)	180	78	2.17	1x1	176	94	1.52	2x2
3 N-420 (Cuenca – Teruel)	160	57	2.48	1x1	150	83	1.48	2x2
TOTAL	**518**	**66**	**7.56**	**1x1**	**497**	**88**	**5.39**	**2x2**

[*] Average Speed
[**] Average Travel Time

The improvement benefits relate mainly to reductions in travel time by the raise of speed and the length decrease in the improved roads. The total travel time savings of the proposed motorway will be approximately 21 kilometers in length, and 2 hours 17 minutes in time although its impact in the shortest path network will not be as higher. The new road characteristics were included in the road network model. Afterwards, we consider the A-40 motorway impact in the shortest path cost motorway road network for HGVs in Spain (see **Figure 3**).

Economic Impact of Introducing a New Motorway on Regional Distribution of Jobs

Employment is considered a key indicator of economic and social performance in most countries. The methodology previously defined in the third section enables us to estimate employment changes linked to transport policy measures by using the monetary value corresponding to jobs included in the columns of the MRIO table as part of final-payments section for each region. The MRIO table considered of the year 2007 has more than 21 million jobs and a GDP of €966,889 million.

The introduction of a new motorway scenario will mean a reduction of transportation costs. This in turn will produce several effects on the regional economy. First, importing and exporting to other regions will be cheaper, so interregional trade will increase. Second, changes in imports and exports will depend on factors such as the value per ton, and the type of the commodities. Third, regional production will replace imports only if the region is able to produce these goods or services internally with lower costs than the imported inputs required, but if the region is not able to do it, the imports from distant regions could be replaced by imports from closer regions. Fourth, exports could be consumed internally securing region productivity instead of being consumed in farther regions which in turn could decrease its productivity. In conclusion, the introduction of a motorway is complex because it causes producer region, distant consumer and supplier region changes according to the transport cost.

The economic impact assessment of the motorway scenario is accomplished through the simulation of the motorway model scenario. The resulting MRIO table shows the changes of jobs in regions (see **Table 5)**. **Figure 4** provides a graphical display of the changes in absolute terms considering both the base-case and the model situation.

Looking at the results, we see that the impact of distribution of jobs at the regional level is quite different depending on the region. The results have shown that the distribution of jobs in the model scenario (motorway A-40) are expected to be located in richest regions and poor regions – compared to the average of the EU NUTS2 regions –. The general situation found in the model scenario is that the overall impact will be positive (increasing Jobs) in Spain. It is explained by the fact that the majority of regions will take advantage of this policy – sixteen of a total of eighteen –. Furthermore, the results have evidenced that poor regions will receive more jobs than rich regions.

The distribution impact might be caused by the fact that the employment level of regions varies since the labor force used to estimate the employment by sector in the regions also varies because it takes into account the rise or shrinkage of output in sectors, and in regions.

The decrease of jobs in some regions shows that these regions will not be able to export sector's goods because of the value offered by remaining regions is more competitive because have improved its efficiency. Moreover, regions in which decrease employment will not be interested in importing other region's sector goods to produce more products even if the transport costs have fallen substantially. Indeed, it explains that these regions' sector goods could be replaced by other regions' goods including its necessary jobs even if they have or do not have a diversified economy (e.g. Catalonia or Galicia correspondingly).

Besides that, other regions as Extremadura, Castile La Mancha, and Murcia have shown a different situation because the impact will be healthier in its economic performance since they are characterized as poorest regions. This implies that its dependency on freight transport road is positive because concentrates its production in freight transport intensive sectors. These regions rely on exports and imports. An explanation might be that these regions are capable of improving its trade with other regions. These results also reflect that levels of self-sufficiency and consumption of regional output will be more important due to the diminishing of transport cost.

Table 5. Employment Impact Analysis (Base Case and Motorway A-40 Model Scenario)

Region		Employment Impact Analysis				
		Base-Case Scenario	**Motorway A-40 Scenario**	**Difference (A-40 – Base-Case)**		
→Richest	Madrid	3,463,500	3.463.790	290	I	0.008%
	Basque Country	1,143,400	1.144.090	690	I	0.060%
	Navarre	354,000	354.576	576	I	0.163%
	Catalonia	3,851,300	3.850.232	-1,068	D	-0.028%
	Aragon	681,200	681.732	532	I	0.078%
	La Rioja	158,400	159.082	682	I	0.431%
	Balearic Islands	538,800	538.851	51	I	0.009%
	Cantabria	270,100	289.728	19,628	I	7.267%
	Castile and Leon	1,167,900	1.173.869	5,969	I	0.511%
	Principality of Asturias	429,500	437.668	8,168	I	1.902%
	Galicia	1,211,900	1.184.383	-27,517	D	-2.271%
	Valencia	2,248,500	2.250.225	1,725	I	0.077%
	Ceuta and Melilla	68,700	68.804	104	I	0.151%
	Canary Islands	889,100	889.152	52	I	0.006%
	Murcia	612,300	614.918	2,618	I	0.428%
	Castile La Mancha	842,900	846.644	3,744	I	0.444%
	Andalusia	3,206,700	3.207.385	685	I	0.021%
Poorest←	Extremadura	422,300	424.116	1,816	I	0.430%
TOTAL		**21,560,500**	**21,579,245**	**18,746**	**I**	**0.087%**

I = Increase
D = Decrease

It is worth noting that expected direct effects in the three regions in which the new motorway runs are positive because they improve trade relations. Also, the indirect effects in neighboring regions will experience healthier effects. In spite of the location of the project, it will change the total accessibility of regions, and this will be indicative of the economic performance. For example, the results showing that the employment in Cantabria region will concentrate additional 7.3% jobs which is by far the biggest winner over the remaining 17 regions even if the region is far from the A-40 motorway (see **Figure 4**).

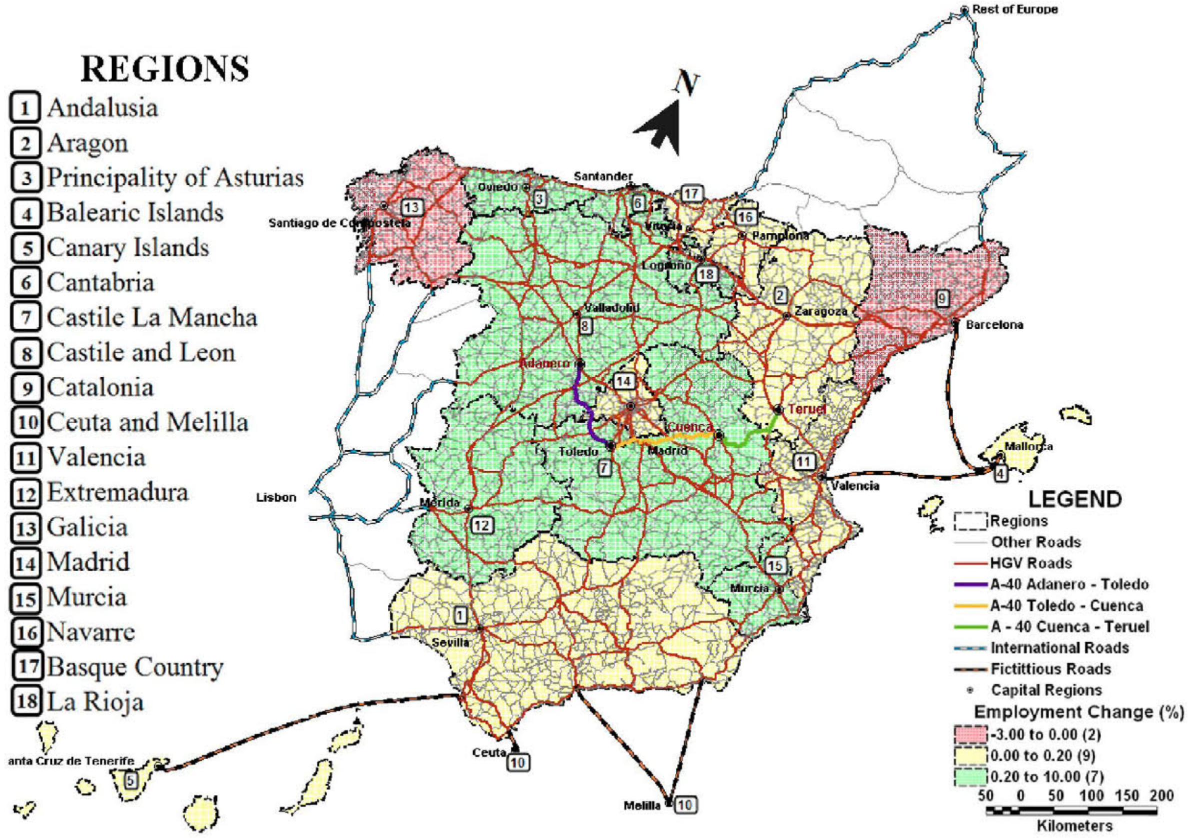

Figure 4 – Employment Regional Changes Model Scenario

Regarding the location effects of the new motorway A-40 in Spain, the results have clearly depicted that the economy has changed regardless of the position of the region in the country. For instance some peripheral (i.e., distant from the center, taken to be Madrid) regions of Spain as Andalusia, Murcia Valencia, Navarre, Basque Country, Cantabria and the Principality of Asturias support the improvement of economy while other peripheral regions as Catalonia, and Galicia will not experience economic effects despite the fact of reduction of transport costs. Consequently, transportation cost reduction has a greater impact on trade in Spanish regions because it eventually might change growth and employment in some regions. Hence, the economic structure of regions could be as much important as the transport costs.

CONCLUSIONS AND REMARKS

The results demonstrate that the model developed in this research is able to forecast the direct and indirect effects produced by a new road on the distribution of jobs. In addition, this model provides a useful tool for policy makers, governmental and transportation authorities to evaluate the impacts of transport policy measures.

The construction of a new motorway in Spain has several effects on the economy of the regions. In general terms the model scenario is expected to rearrange trade flows, and relocate interregional trade since transport cost of goods has decreased. As a result, overall employment in the economy increases because of the raise in the interregional trade. This situation has evidenced that the effects of the infrastructure will take place including outside regions in which the project takes place. The intuitive result found is that lower transportation costs lead to distributive impacts because jobs are relocated, and does not evidenced generative impacts since GDP and prices of products in both cases remains constant.

Different explanations could be proffered for that finding. Some could be focused in the capability to generate more production and consumption due to the fall of transportation costs. Others could be referred to the location of regions, and others could be related to the economic structure of the regions. The model scenario has revealed that transport costs' reductions are one amongst many of the factors that shapes the economic performance of Spanish regions. In addition, it has supported that transportation is linked to development and to the functioning of regions and economic sectors through the facilitation of trade, and it also has provided evidence that the different economic activities of regions have influenced the economic performance.

For example, regions which based their economic activities on road freight transport intensive sectors in more than 80% as La Rioja and Navarre will not be benefited as much as Cantabria, Extremadura and Castile and Leon. However, in other regions which meet their economic structure on road freight transport intensive sectors in less than 30% as Madrid, Balearic Islands and Canary Islands will also register rather small employment distribution. In conclusion, the model has evidenced that the distribution of employment in regions takes into account the economic structure of regions as well as the efficiency brought by the improvement of the transportation infrastructure.

Although the methodology applied is sophisticated enough to obtain sufficiently reliable results, there is still room for improvement. The first set of limitations stems from the current availability of data. It would be desirable to have more detailed data regarding IO tables for provinces within Spain regions in order to include greater interregional representation which would allow more complete results. Moreover, IO information from other countries would improve the representation of exports and imports. In addition to this, much more complete information about other transportation modes used in the EU would enhance the applicability of this approach.

Finally, this model could be a powerful tool, as well, in the assessment of the impact of changes in nationwide transportation policies.

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