International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:11, 2017

Deterministic Modelling to Estimate Economic Impact from Implementation and Management of Large Infrastructure

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***Abstract*—**It is widely recognised that the assets portfolio development is helping to enhance economic growth, productivity and competitiveness. While numerous studies and reports certify the positive effect of investments in large infrastructure investments on the local economy, still, the methodology to estimate the contribution in economic development is a challenging issue for researchers and economists. The key question is how to estimate those economic impacts in each economic system. This paper provides a compact and applicable methodological framework providing quantitative results in terms of the overall jobs and income generated into the project life cycle. According to a deterministic mathematical approach, the key variables and the modelling framework are presented. The numerical case study highlights key results for a new motorway project in Greece, which is experienced economic stress for many years, providing the opportunity for comparisons with similar cases.

***Keywords*—**Quantitative modelling, economic impact; large transport infrastructure; economic assessment.

I. Introduction

DECISION-makers have long been concerned with whether large transportation infrastructure investments lead to economic development [1], [2]. Decision-making implies making choices, and in the case of large transportation infrastructures, those related to decision making for budget allocations and selecting between alternatives for a new road or a new railway or another large transportation infrastructure project [3]. The decision-making process for large transport infrastructure projects usually is made under high risks and uncertainties. The key question in such decision-making processes is if the socioeconomic impact of the new large transport infrastructure project could contribute to the whole economic system and boost economic growth in terms of jobs and income [1].

Governments and decision-makers promote public investments in large transportation infrastructure projects in order to achieve socioeconomic goals. Arguments for significantly boosting investments, especially in large infrastructures in order to achieve sustained growth, rest on the high returns to investment in capital scarce environments, and the pressing deficiencies in these areas. One of the most critical issues of decision-makers is to select which public investment projects will be funded in order to encourage economic growth, particularly during periods of economic downturn [1], [3].

The first stage decision-making process is the development of demand analysis, based on the sensitivity of critical variables such as: demographic and socioeconomic changes, travel demand characteristics, capacity constraints and spatial changes [4]. Then the optimum project should be identified after the assessment of all promising strategic and technical alternatives on the basis of physical circumstances and available technologies. After selecting the optimum option, the expected outcomes of this optimum investment option have to be considered. Some key expected outcomes are: unemployment reduction, prevention of environment damage, national income growth and competitiveness increase [5]. From this point, the answer to decision makers of which projects should be financed by public support is to choose projects that maximize the benefit criteria mentioned above with the lowest cost. However, the complex nature of decision-making requires to select investment options based on a wider variety of economic and social considerations [1], [6].

II. Economic Impact Assessment Structure

There are many cases where organizations and governmental authorities do not maintain a clear distinction between the investment options, thus between the effectiveness and efficiency of an investment activity, resulting in many uncertainties and risks. Especially, the decisions for the implementation of large infrastructure projects such as motorways, where large amounts of capital are reserved, may be very complicated, and the financing mechanism may be a major concern in planning process and strategic analysis.

The key objective of the assessment of the economic impact of large infrastructure, such as motorways, is the ex-ante appraisal of large transportation infrastructure projects' economic effects on the national economy. Conventional wisdom is to analyse and quantify the economic effects of large infrastructure projects and review the added value of the investment in the national economy and the society as a whole, in terms of total generated new income and new jobs. The outputs of this assessment provide an essential tool to decision-makers in order to be able to:

- Plan and define the needs for new infrastructure;
- Promote efficient and effective investments, minimizing the project uncertainty; and

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- Prioritize the projects development phases to meet funding and business goals.

The assessment outputs should be used as an effective tool by decision-makers, government authorities and stakeholders to define conclusions about the economic effects of large investment in infrastructures, supporting decisions in:

- National/Regional/Local economic system sustainable growth and competitiveness;
- Review the added values from the implementation of a new infrastructure projects, where huge amounts of capital are reserved and the investment payback may extent to a long time horizon; and
- Prioritize public funds and attract private investors and equity to secure project budget and financing.

It is noteworthy that in most of the cases, the planning, development, implementing, financing and delivering issues for large infrastructure projects may take from some years to some decades, involving many different stakeholders and agents in the decision process. An overview of the complexity in terms of objectives, tasks and expectations between different decision-makers is presented in Fig. 1.

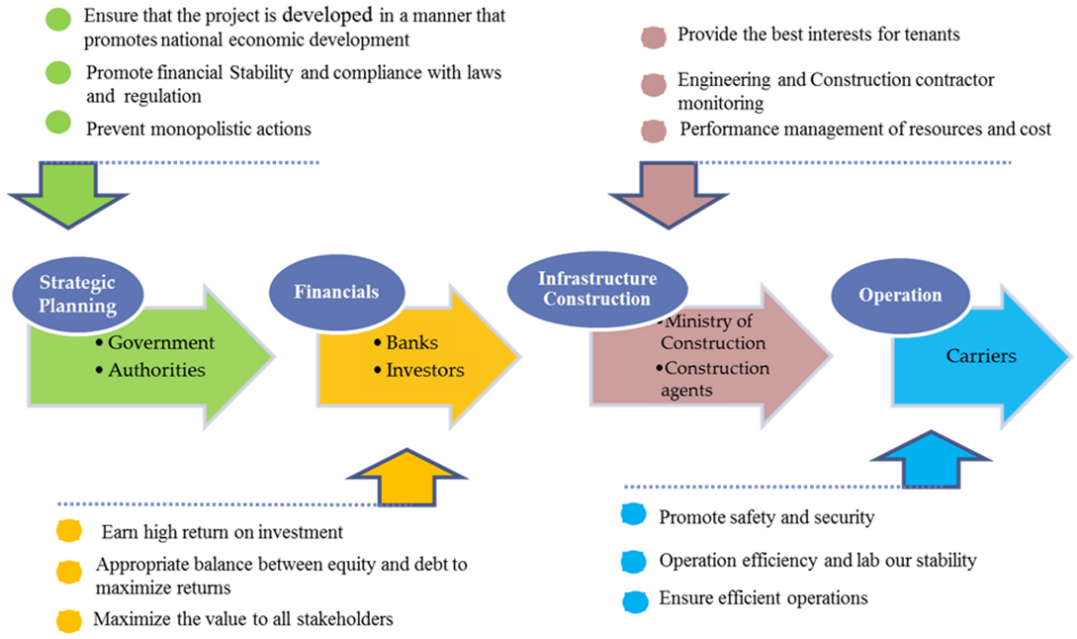

Fig. 1 Group of stakeholders involved in decision making during large infrastructure project life cycle [7]

The estimation of the economic outputs in regional economy is the base for decision-makers and stakeholders involved in the large project life cycle. Therefore, an estimation of each task's economic impact is critical to supporting decisions concerning business sustainability, performance evaluation and economic productivity of a large infrastructure project.

III. Evaluation Principles and Objectives

Conclusively, the economic impact of the transport infrastructure development and its robustness depends mainly on:

- The level of collaboration between all stakeholders, public authorities, private companies, transport infrastructure administration, and local governors;
- Providing connectivity and accessibility with other modes of transport, especially highway and railway networks that accommodate the highest proportions of traffic demand;
- Keeping the overall and sectional efficiency of the operation at a customer satisfying level to offer a fair advantage over its competitors in the commercial market;
- The availability of financial sources and economic supports; and
- Maintaining strong economic output to the local and regional economy.

The key challenge for the economic assessment of policies, regulations and actions towards sustainable development of a large infrastructure project, is drawing up a classification of a set of measures according to pre-set decision objectives with respect to economic growth and employment, environment and nature and landscape quality, social goals and aspects of the quality of the living environment.

Therefore, the base for the decisions towards sustainable development of an infrastructure project is the economic outputs cause to the infrastructure project. Therefore, the evaluation of the economic impacts for a new motorway corridor or a new airport must recognise and characterise the type, the location and the outputs of the business heavily related to this project. This is as important as understanding where the relative probabilities and densities of change of businesses are.

The spatial dynamics of business development will be linked to the potential socioeconomic impacts that will drive regional economic development. The detailed projection of business density development will be a tool to highlight the effects of decision making.

A range of published metrics designed to measure economic activity performance, including the internationally recognized Gross Domestic Product (GDP) and a range of Socioeconomic Value measures could provide results in terms of added value and new jobs generated by the examined activity. Focused on assessing the feasibility and the economic footprint towards the development of a large project, four key assumptions for measuring the economic impact should be adopted:

- Creating a methodology which is broadly consistent with international standards for measuring outputs;
- Developing and accessing valuable, reasonable and multi-parametric scenarios for the estimated future economic conditions, financial factors and capital source and availability; and
- Using a group of indicators or assessing factors which impact socioeconomic system to provide an indication of which providing results regarding the greatest impact on a local, regional or national scale.

The economic output calculations must consider related issues, including, amongst others: data consistency and quality; direct, indirect and induced impacts; and price inflation.

There is necessary, also, some marginal testing on legitimacy and regulatory willingness related directly to the existence of market weakness, and even failure, as a justification for regional government intervention. This type of analysis grouping policy to three categories of measures/ actions, which can be distinguished as:

a) Robust measures deliver tangible direct advantages in terms of the immediate goal; any undesirable side effects can be mitigated at reasonable cost; the advantages are such that the benefits may be expected to outweigh the (financial) costs; no better alternatives are evident.
b) Upgradeable measures are those that do not satisfy the criteria listed under (a) on some points. A necessary condition is, however, that the measures could be potentially robust in another form or in combination with a different policy. It is often a question of measures for which the scale seems out of proportion, or the risk profile unnecessarily large, or where a further drive for harmonization or specification is necessary.
c) Weak measures are not very effective or efficient, and according to expectations, would also fail to yield a high social gain with another design in a short time. The justification for government intervention is often also questionable in this category.

Conventional wisdom is to provide estimations about the economic outputs and the added value caused of the new project providing the appropriate background to:

- Define policies towards sustainable business development;
- Review policies and actions towards better life conditions for locals and visitors;
- Mitigate the investment risks;
- Reduce barriers to entry for new economic activity;
- Stimulate the business interest; and
- Assess the added value delivered by dedicated plans and actions.

The depiction of economic activity is essential not only to provide essential messages to decision-makers and land use planners, but also to develop, assess and support activities providing positive contribution to the regional economy. Therefore, the assessment objectives could be concluded to:

- Estimate the economic impact of an implementation plan;
- Review the efficiency in the existing economic system in terms of job, income and business creation;
- Determine the added value towards economic enlargement in terms of capital investments, business activity long term standing and improvements in quality of living for residents and visitors; and
- Monitoring and assessing the business activity spatial allocation to meet the regional and national goals in terms of sustainable development and increased land-use productivity.

IV. Methodology Framework

To determine the economic impact assessment of economic activity in spatio-temporal terms, the key research question deals with the review of the economic outputs and sustainable development goals. Based on Balanced Scorecard (BS), the performance of the business and activities economic outputs against strategic goals of sustainable development will be reviewed [8].

The BS framework is referred to those that created by Kaplan and Norton (Harvard Business School) as a performance measurement of Key Performance Indicators (KPIs). The benefits of this methodology framework deal with the evaluation of a set of indicators related to financial metrics and non-financial performance measures of a system, providing essential results to review progress and benchmarking with relevant case studies. Furthermore, weighted multi-criteria analysis, Analytic Hierarchy Process (AHP), will be implemented [9]. The diversity of factors involving institutional problems in decision making requires that the organizations deal with the multicriteria approaches. The investigation of problems related to economic growth, sustainable development and investments requires due to the complexity of the variables involved, the use of assessment considering multiple criteria [7].

Among the tools of sustainable business development implementation to be considered by the promotion of dedicated actions, include investments, emissions mitigation, cost reduction, accessibility to markets etc. All those constitute key factors that drive business and market development, enhance productivity, extend trade circulation and promote economic development, or in other words, all factors that are necessary to remain competitive as an economy and productivity system. However, the key challenge is the geographically distributed actions, aiming to provide an

increased regional integration and the reduction of inequalities. In addition, the development of alternative development scenarios is based on a set of economic and non-economic criteria [10].

The set of criteria include direct effectiveness of policy and measures in terms of the sustainable development goal, the most important effects on other key policy goals, and the efficiency of the measure (in terms of financial costs and the quality of alternatives). The key categories of criteria for large transportation projects include:

a) Economic/financial: related to the benefits and costs of investment or business activity over a determined period (project horizon);
b) Mobility/logistics: all parameters are related to the improvements in the transportation/mobility system where the tasks are inserted, considering transportation physical and operational indicators;
c) Social: characterized by the direct and indirect effects estimated in social analysis and I/O analyses outputs; and
d) Environmental: related to the impacts generated by the promoted activities that will be caused in the physical, biotic and anthropic environments.

V. Modelling Dimensions and Assumptions

Evaluating an investment in a new infrastructure large project, by a systematic approach, promoted to follow a deterministic mathematical approach where the output of the model is fully determined by the parameter values and the initial conditions models. The goal of this approach is to derive a set of multipliers that will give the opportunity to decision-makers if they know an initial change in output, earnings, or employment that will be created directly from a major infrastructure project (construction and operation phase), to be able to calculate the total economic impact to the whole region in order to support the final decision for the development of such a project.

The systematic approach for the mega-project economic impact assessment used in this paper is depicted in Fig. 2.

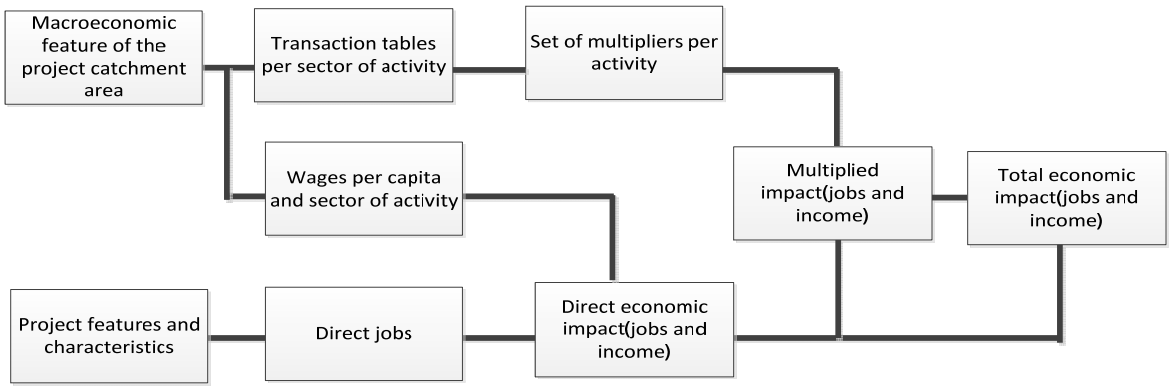

Fig. 2 Systematic approach of economic assessment flowchart [3]

The criteria that are most important for governments and decision-makers when they intend to evaluate new large infrastructure projects such as motorways proposals are:

(1) Growth in economic activity: the total economic activity resulting from the project may be expressed as income or value-added;
(2) Increase in employment: the total additional employment expected to result from the project including construction, operation and maintenance and any other businesses supported by the project daily activity and business development, including infrastructure construction, operation and maintenance and any other businesses supported by the project daily activity and business development [8].

The conceptual basis for the economic impact footprint analysis of the new income and employment created due to a new infrastructure project investment is the input–output analysis (I–O) [1]. Input-output analysis provides multipliers that can be used to estimate the economic wider effects that an initial change in economic activity causes on the regional economy. The change in final demand is the change in different business sectors caused by a new infrastructure development projects or an increase in exports [11].

The I–O analysis is based on the transactions of each business sector. I–O transaction tables represent the production structure of an economy by the income generated in each sector for a given time. I–O tables are matrices by product and industry describing production processes and products' transactions in great detail. Industries are classified according to Nomenclature statistique des Activités économiques dans la Communauté Européenne (NACE) and products according to Classification of Products by Activity (CPA) [12].

VI. Case Study

Adoption of the Euro in the 2000s allowed Greece easy access to foreign borrowing and private credit growth following by financial liberalization that boosted household consumption. The Greek economy achieved high growth rates until 2006, showed signs of recession in 2007, whereas from 2009 onwards the recession has been intensified considerably

due to country's fiscal imbalances.

The need for consolidation has led the country to embark on a trilateral mechanism of financial support, comprising the EU, the International Momentary Fund and the European Central Bank (IMF 2014). The restrictive income policy and drastic limitation of public expenses during the past few years had a negative impact on GDP as well as on employment [13].

The case study provided to illustrate the methodology framework is the construction of a large transportation infrastructure concession project, and specifically a group of four motorways in Greece.

The total investment cost for the four motorways reached the amount of €4.6 billion, which is very high for the turnover of the Greek economy. The project was divided in two distinct periods:

i) The construction period ("T1"), which includes the design and construction of the necessary infrastructure for the operation of the full length of the motorways and the management of the traffic during the construction period.
ii) The operation period ("T2"), which includes the operation and maintenance of the infrastructure. The construction period started in 2014 and ended in 2016. And the operation period in the concession contract is 30 years.

Fig. 3 Concession motorways in Greece [3]

Overall, the contracts foresee the construction of 680 km of motorways, the upgrading of 459 km of existing roads and operation of 1188 km (Table I). Analytically, the group of the four concession motorways, as depicted in Fig. 3, consists of:

1. Ionia motorway-M1-Ionia motorway (part of the priority projects of the TEN-T network).
2. Olympia odos motorway-M2-Olympia Odos is included in the Trans-European Transport Network (TEN-T) as part of the Pan-European Axis IV integrated in the new concept of Trans-European Multimodal Corridor IV.
3. Aegean odos motorway-M3-Aegean motorway is part of the priority projects of the TEN-T network, which connects Greece to the rest of the EU1.
4. Central motorway E-65-M4-The Central Motorway is included in the Trans-European Transport Network (TENT) as part of the European Corridor E-65.

Direct employment in the three years of construction reflects the same mix of job types, although the number of on-site and off-site positions is scaled proportionately to the relative magnitudes of first, second and third year of

construction costs.

TABLE I
MOTORWAY CONCESSIONS TECHNICAL CHARACTERISTICS

	Length to be constructed	Length to be upgraded	Length to be operated
M1	196	172	360
M2	25	205	230
M3	284	82	366
M4	175	-	232

Except direct, indirect and induced effects, the improvement of the interregional transportation infrastructures is expected to affect the trade through the changes in geographic distances and transportation cost and by altering the factor 'productivity', estimated as catalytic effects.

The four-motorways concession project will result in an annual increase of the total annual income ranging from €220 million to €1200 million for the three years of construction, as depicted in Fig. 4.

Analysing the forward linkage sectors of the average annual estimated macro-economic effects associated with the project, it is highlighted that many sectors of the economy will enjoy increased activity in comparison with others.

Considering the existing business development model and the regional spending transactions in I–O analysis, the top sectors that achieve the highest multipliers will be the construction sector, wholesale trade and industries including energy. This indicates that a unit change in final demand in these sectors will create an above average increase in activity in the economy.

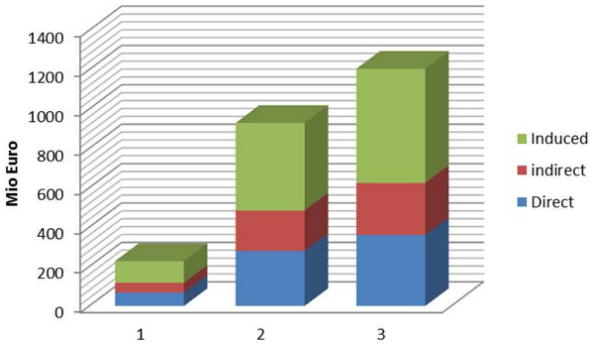

Fig. 4 Economic impact footprint data analysis [3]

VII. CONCLUSIONS

The results suggest that investment in motorways spurs economic growth and generates employment directly through the actual construction, operation and maintenance of the project but also through indirect and induced multiplier effects across the economy.

There is also a strong relationship between economic infrastructure investment and sectors of construction, industries including energy and trade, reflecting the role of such investments on job creation through construction, maintenance and the actual operational activities, while increased employment could in turn contribute to further infrastructure investments indirectly through the multiplier effects across the economy.

The results provide strong evidence of the existence of long-run cointegrating relationship among economic growth, infrastructure investment and unemployment reduction investigating the high level of coverage of national socioeconomic targets caused by new large transportation infrastructure projects.

The Greek economy is in its eight year of financial stress, with unemployment reaching high levels, particularly among youth. Greece is a typical example of how a small country suffering from recession and the development of a mega projects such as motorways changed the economy tendency moving toward higher Foreign Direct Investment (FDI) impact in the economic system and conditional market changes stimulating new business and investments, moving up onto an economic development path. Potentially, these large-infrastructure projects provide substantial economic opportunities, and the key challenge for government agencies, authorities and stakeholders is to be prepared to achieve the benefits in an efficient and effective manner.

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