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Decision Framework for Cross-Border Railway Infrastructure Projects

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Abstract**—**Transport infrastructure assets are key components of the national asset portfolio. The decision to invest in a new infrastructure in transports could take from a few years to some decades. This is mainly because of the need to reserve and spent many capitals, the long payback period, the number of the stakeholders involved in decision process and –many times- the investment and business risks are high. Therefore, the decision assessment framework is an essential challenge linked with the key decision factors meet the stakeholder expectations highlighting project trade-offs, financial risks, business uncertainties and market limitations. This paper examines the decision process for new transport infrastructure projects in cross border regions, where a wide range of stakeholders with different expectation is involved. According to a consequences analysis systemic approach, the relationship of transport infrastructure development, economic system development and stakeholder expectation is analyzed. Adopting the on system of system methodological approach, the decision making framework, variables, inputs and outputs are defined, highlighting the key shareholder's role and expectations. The application provides the methodology outputs presenting the proposed decision framework for a strategic railway project in north Greece deals with the upgrade of the existing railway corridor connecting Greece, Turkey and Bulgaria.

Keywords**—**System of system approach, decision making, cross-border, infrastructure project.

I. Introduction

CONTINUOUS growth of global container volumes causes increasing needs on the inland road, water and rail connections, especially in developed countries with financial restrictions for new infrastructure development. Simultaneously, cross border rail connections require more reliable connections because their supply chain demands for just-in-time delivery, and the environmental impact of the rail transportation is lower than the other inland connections. In this paper, a decision support system for investing in new cross-border railway projects is developed.

Transport infrastructure development is a decision making process that involves multiple stakeholders, specifically: Government and governmental authorities, investors, and operators. The highest level goal of the decision making process is the delivery of cost effective, reliable, sustainable, efficient, convenient and safe rail connection and other services to the state's population.

A system-of-systems approach framework developed will link all key transport infrastructure stakeholder concerns in different levels of the transport infrastructure development decision making process. The application is for the cross border rail sector.

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II. Literature Review

One of the most important issues of the decision making process in order to invest in new infrastructures in transports by funding agencies is which projects they should spend their limited resources on. These decisions can be supported by Decision Support Systems and frameworks which synthesize appropriate techniques of decision analysis and optimization techniques based on evaluation criteria [1].

There is a considerable range of decision support systems frameworks reported in literature applied to a range of issues such as energy planning decisions, urban infrastructure planning, increase freight rail capacity towards truck capacity. Taking into account the fact that many countries all over the world take more and more decisions in order to go on energy planning, due to the climate change, there is an increasing dee a need for development of decision making frameworks that will support this strategic planning. Codina et al. [2] analyse the fact that large scale frameworks that support decision making for strategic planning on energy are often very complex. Even if in many other energy strategies economic optimization is used, Codina et al. [2] due to the high complexity of economic optimization, give a simpler modelling framework, designed to support decision-makers by improving their understanding of the whole energy system, intending to give the potentials of the policy and investment decisions on final energy consumption, total cost and environmental impact [2]

Countinho et al. [3] highlight that the planning of urban infrastructures is a decision making process with many criteria. The evaluation of multiple alternative criteria such as social, economic, and environmental, gives a decision support system that is a tool for all stakeholders (e.g., government or municipalities) [3].

As Rowangould [4] describes that public funds are spent in order to increase freight rail capacity and the demand of transportation load by rail. While the benefits of rail transportation are obvious, it is a question if decision makers can effectively identify the appropriate rail investments for funding that will help them reach their policy goals. Rowangould gives an overview of the analytical methods, models, and data that are commonly used to support decisions for freight rail infrastructure projects with private financing, analyzing a case study of California's Trade Corridors Fund program for 11 freight rail projects, and identified the key challenges and potentials for the decision making framework [4].

Methodologically, there is a variety of models, from simple multi-criteria decision analysis and prioritization models to complex models of portfolio optimization.

Multicriteria decision analysis is increasingly used for decision-making in environmental policy evaluation due to the complexity of issues and the inadequacies of conventional tools such as Cost Benefit Analysis (CBA) or Cost-Effectiveness Analysis (CEA) for capturing the full range of impacts of a policy or capital project. [5]

Browne et al. examine and compare the use of a number of policy evaluation tools, which can be used to measure the impact of transport policies and programs as part of a strategic environmental assessment (SEA) or sustainability appraisal. The evaluation tools include CBA, CEA and multi-criteria decision analysis (MCDA), concluding that both CEA and CBA are useful for estimating the costs and/or benefits associated with transport policies but are constrained by the difficulty in quantifying non-market impacts and monetizing total costs and benefits. [6]

Lourenço et al. [7] address the problem of selecting a robust portfolio of projects in the context of limited resources, multiple criteria, different project interactions and several types of uncertainty, identifying all efficient portfolios and depicting the respective Pareto frontier within a given portfolio cost range, and permits users to analyze, in depth, the robustness of selecting a proposed portfolio. [7]

III. Methodology

The methodology is based on breakdown analysis and System of system approach. The problem conceptualization is based on the identification of the key parameters that stakeholders and decision makers set in order to invest in transport infrastructures, and monitor the system performance with desirable economic and social outcomes. Assessing the "performance" of any complex socio-technical system, is challenging because it encompasses several, often competing key parameters and diverse stakeholder perspectives.

Several different parameters and structural features of transport infrastructure projects conceptually represent how those features can enhance performance. The different parameters that are critical to cross border rail infrastructure are identified. The aim is to characterize the competing objectives and parameters that stakeholders and decision makers face worldwide by a holistic approach analysis.

The process for considering various forms of investing in rail projects involves a multi-step process starting with identification of the different stakeholder's goals and objectives, comparison of those goals, identification of ways to mitigate stakeholder risks, review of the transaction's complexity and risk. Decision making theory and strategic planning generally involve setting targets and determine critical issues and key parameters to achieve these targets. The potential key issues of the strategic planning and decision making to discuss for project development include: (1) Strategic planning in order to stimulate competition and (3) Business Planning.

Stakeholders want to ensure the project is developed in a manner that promotes regional economic development and create an operating environment that encourages increased passenger traffic and market development. A key issue also is to take actions to increase traffic levels, drive efficiency and introduce innovation. Continuous changes to traffic growth, regulatory framework and market developments require huge investments into infrastructure to comply with international standards and to stay competitive. In addition, parameters as to attract service and encourage economic development by travel costs and reduced operating expenses, improve customer service and quality.

A. Overview of the System of System Approach theory

In the last years a lot of interest has been given to the concept of "System of Systems" (SoS) which has attracted interest in many fields of applications. The system of system concept describes the relation of many independent systems, which are integrated in order to reach a target of a national goal.

Many case studies and applications, such as air and road transportation, energy, healthcare, water management, large infrastructure projects, can be found in literature [8], [9].

Systems of System approach is an approach with complicate interactions between the various independent systems [10]. A system, in general, is a combination of the different independent systems to define a function or set of functions [11]. Each system of system has distinguishing traits [12]. A successful analysis of projects using systems thinking is contingent on correctly identifying these distinguishing traits.

B. Multi-objective Decision Analysis Involving Multiple Agents

A crossborder rail infrastructure consists of large networks of interrelated components which produce and transport resources. Like other engineering systems, they are large-scale, high-cost, and long living, motivating strategic decisions for the develop, design and operation to maximize life-cycle value. With an emphasis on sustainability, life-cycle value can be decomposed to economically efficient performance, environmentally impacts, and social return.

Transport Infrastructure systems are often independently managed by multiple public agencies and commercial firms and operate more like a collaborative system-of-systems. The lack of a single central agent in a directed system of-systems is a barrier to widespread system-system integration between consequents. In the absence of a central agent, the best integration of component systems, is a significant challenge to decision making process in order to invest in new rail project.

The most significant distinguishing traits of SoS framework in decision making in order to invest in a new rail cross border rail infrastructure include strategic planning, infrastructure planning, financial issues and operation. For each objective an agent as Government and Authorities, Construction Agencies, Investors and Carriers is responsible as described analytically in Fig. 1. These traits and the different agents have different issues and concerns and perspectives on the potential key parameters.

C. Crossborder Rail Project Decision as System of System

Based on the distinguishing constitutes as multiple objectives, a SoS framework is proposed as a methodological structure for assessment of evaluation in crossborder rail projects. Decision process to invest in Crossborder railway projects is conceptualized as SoS with sub-systems consisting of different constituents. By capturing the dynamic behaviors, uncertainties and interdependencies of these constituents, the evaluation of rail projects can be evaluated as described analytically in Fig. 2.

Assessing concrete steps across a project's investment decision making process can be a powerful way of making it more resilient and ultimately more profitable for all of the stakeholders and agents across the value chain. Fig. 1 provides an example of a generalized System of System framework.

First step: Strategic Planning: Governments are responsible for the strategic planning in order to develop projects with correct forecasts and assumptions (for example, on demographics, demand, prices, revenues, capital expenditure, or operating expenditure), and a high understanding of market dynamics. They have also to plan for volatility and adverse scenarios.

Other challenges of the government and authorities include planning and management of future interface risks, caused by early-stage decisions regarding project structures and design. In addition, the risk of contractors, and private investors, who are essential, has to be taken into account in the phase of strategic planning.

A system of system approach involves making decisions using a risk-based perspective. Specifically, in the earliest design and planning phases of a rail project, this may require a conscious effort to identify, assess, and, quantify all the risks the project will be exposed to across its life cycle. This includes reflection on potential adverse circumstances and scenarios that has to be made by governments and authorities. The objective is to create a decision-making process to select the most suitable investment that will achieve the national targets and ensure the project is developed in a way that promotes regional economic development.

Second step: *Determine financial issues:* Because governments take financial risks in public-procurement structures, they should structure their investment and manage their risks as private investors do. This could clarify their knowledge and application of available alternative risk-allocation models (for example, outsourcing of operations and maintenance activities), but could also result in a changed approach to how public funds are "allocated" within the government.

Overestimating revenue and growth potential while underestimating risk results in note efficient designed projects may deliver lower-than-expected returns or, in the worst case, may cause cancellation after significant up-front investment.

Third step: Infrastructure construction: The stakeholders in the construction phase that have to do with engineering and construction contractors are responsible for on-time, low-cost, and high quality construction and financing. Many problems may arise when stakeholders in the construction phase have cost overruns and delays, or are not able to perform their contractual obligations due to their low profitability.

Fourth step: Operation management: In this phase of a project, asset owners and investors or concessionaires are the stakeholders that are related to the operation and maintenance contractor monitoring, while operational and maintenance contractors are responsible for ensuring on-time, on-budget, and on-quality operation and financing, through KPIs efficiencies in order to avoid delays and increased costs.

A design or construction interface with the operational and management system of system approach contractor should be planned and managed early on and the long-term implications of current design alternatives evaluated. They also have to apply forecasting techniques and KPIs planned under adverse scenarios.

For the purpose of integrated evaluations assessment, the SoS framework analyzes project investment at three levels: base level (inputs), process level, and project level (output) as analytically described in Fig. 2. This three level analysis facilitates a bottom-up approach for evaluation assessment from the base level to the outputs. The inputs are the operation characteristics and the rail operator performance. The outcomes are obtained by aggregating the multiobject agents and interdependencies of constituents at the level of network planning, taking into account all the social values and economic conditions.

As shown in Fig. 2, the interactions between agents, at the base level are aggregated to give the outputs concerning business sustainability, network evaluation and economic productivity of a new rail cross border project.

IV. Case Study

Accessibility is the basis for economic competitiveness, social and regional cohesion and cultural development. The railway connection between Bulgaria and Greece can play an important role in the socioeconomic development of the two countries and the wider region.

The decision framework is applied in a strategic railway project in north Greece deals with the upgrade of the existing railway corridor connecting Greece, Turkey and Bulgaria.

The objective of the decision making framework has been to assess strategically the overall need and potential for developing Cross border Rail connection and to provide recommendations for project implementation of the most suitable development option for the project.

Nowadays, the existing railway corridor makes little use of rail transport for north-south bound international passenger and freight transport. The existing network is of poor quality. The level of service and the speed is low and there are barriers for interoperability with the rest of the EU due to differences in standards.

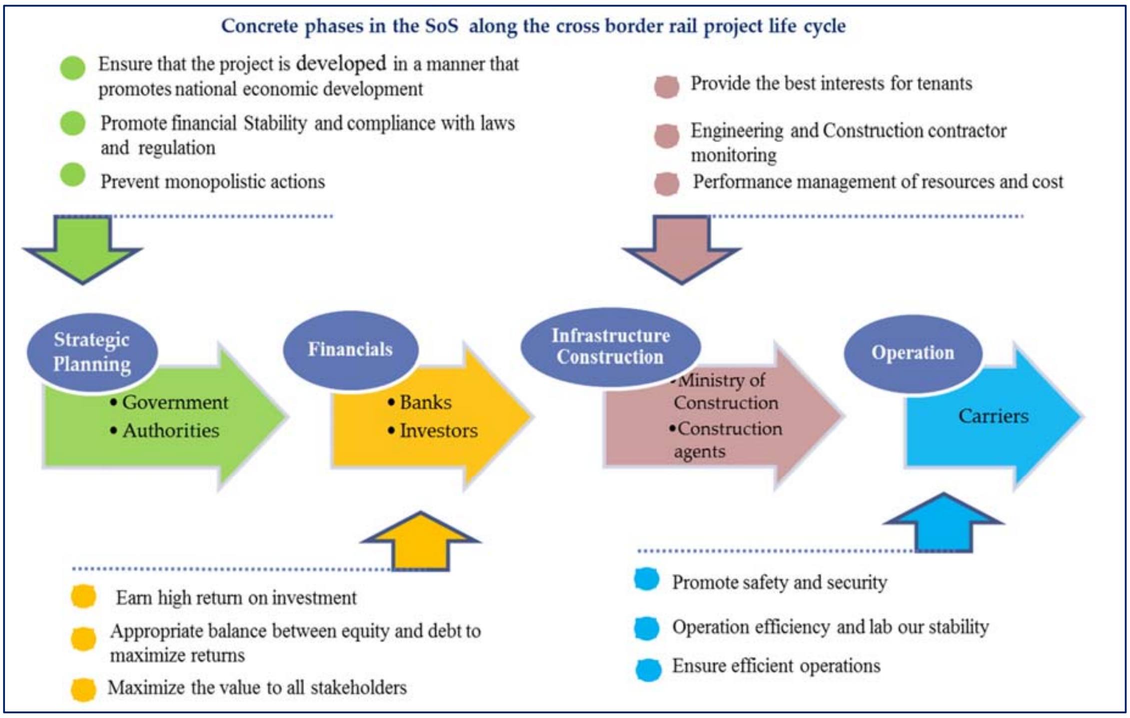

Fig. 1 Phases in the SoS along a cross border rail project life cycle

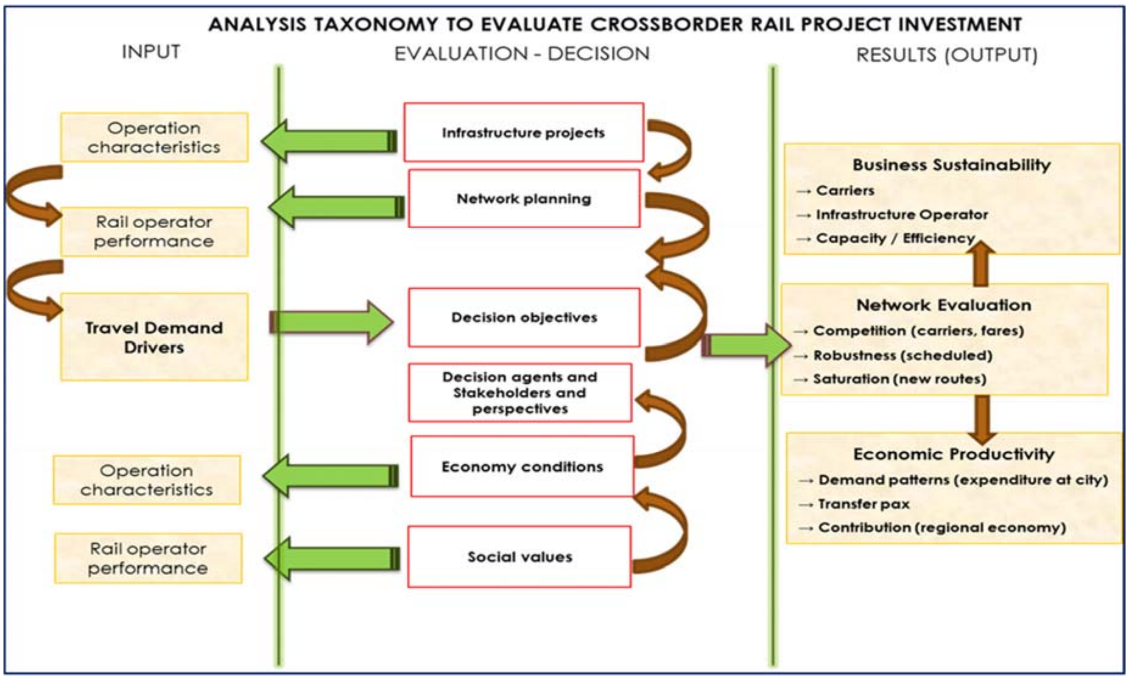

Fig. 2 Analysis taxonomy to evaluate cross border rail project investment

The target behind the upgrade of the Rail connections is to develop high-quality connections for passenger and freight transport between the Greece, Turkey and Bulgaria as well as between the Greece and other EU countries. Improved rail lines will result in more efficient connections between the Greece and the other Countries (particularly Bulgaria) and in the long run potentially further to Asia.

Improved rail links will benefit the environment; contribute to decrease congestion on the road network, increase the accessibility of the Black Sea and potentially improve conditions for accelerated regional economic development.

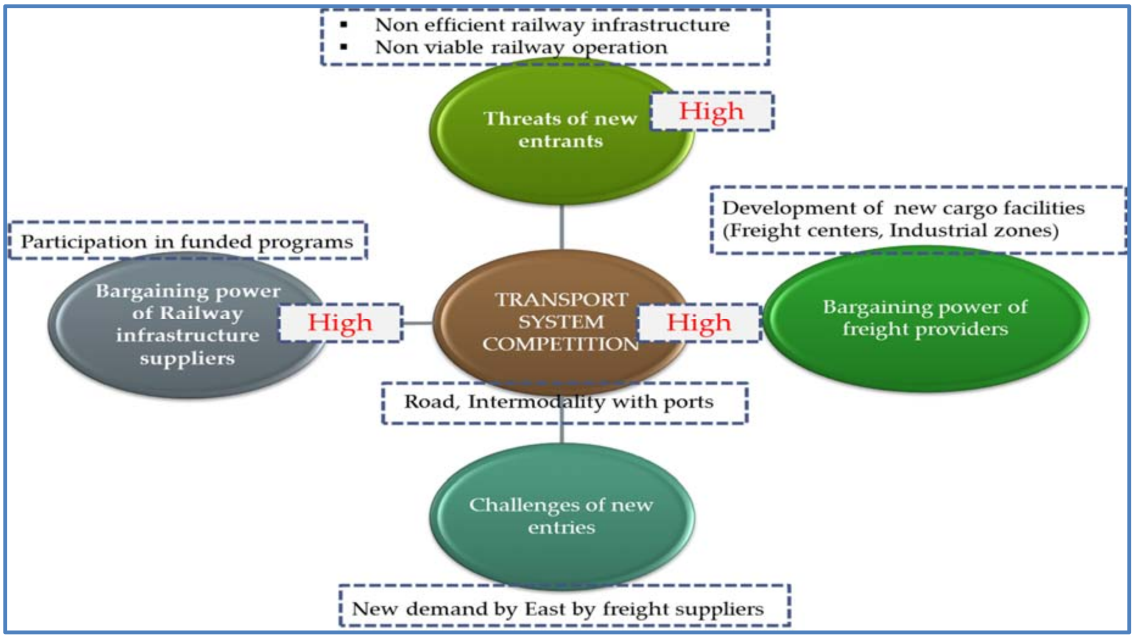

Fig. 3 Porter analysis for cross border rail infrastructure project development

A good and cost-effective transport system will lead to high economic growth and improve the European integration and increased accessibility to Asia.

A. Strategic Planning Issues and Strategy

The strategies of enhancing the interoperability and rail network in the two countries targeting the effective interconnection of the region with the Pan-European Corridor VII. The development of transit hubs includes infrastructure development of integrated management through multimodal land (road and rail) with the network of international ports in the region.

Railway network can fully serve the needs of mobility to address East-West cross-border links with all of the aspects of development and with the Pan-European corridors in the direction North-South leading to the integration of the competitiveness of the country.

Applying Porter's five forces analysis, a framework adopted that attempts to analyze the level of competition within the transport industry and business strategy development, Fig. 3 derives five forces that determine the competitive intensity of transport system in the cross border region and therefore the attractiveness of the cross border rail infrastructure project.

B. Financial and Risk Issues

Railway infrastructure investments have, in general, difficulties in attracting private risk capital due to the often large uncertainty associated with these investments.

In order to improve the financial situation for both rail operators and rail infrastructure managers, it is - independently of the choice of investment option - recommended to carry out specific analyses to assess if present rail access and rail tariffs are optimal for infrastructure managers, rail operators and users, respectively.

The most important risks elements, which can influence both investment costs and timing, are:

- Investment costs escalation
- Funding schemes
- Traffic demand
- Environmental risks
- National strategic planning risks
- Trans-national co-ordination risk may be high

C. Management and Organization Challenges

The stakeholders and government must well establish co-ordination arrangements, so there is a basis for creating a coherent management structure for the implementation of agreed development plans between countries.

The project requires very detailed coherent strategic planning and management among the countries to agree on all technical specifications and alignments - and, very importantly, on the timing for the construction of the various sections, which also means close coordination on financing plans. The trans-national business development has to be done in a dedicated organizational structure involving staff from all involved countries. Furthermore, a strong focus on maintaining or improving the attractiveness of rail transport in the coming 5-10 years' developing period in order to ensure that there is a good basis for utilizing the investments made in the region when they are completed.

V. Conclusions

Delivering transport infrastructure is a complex enterprise involving many stakeholders; Government and planning agencies, finance organizations, private contractors, system operators. As the goal of the decision making process is the delivery of cost effective, reliable, sustainable, efficient, convenient and safe rail connection, a system-of-systems approach framework was developed in order to describe and link all key transport enterprise stakeholder concerns and involvements in the transportation project delivery process.

The trans-national agreed strategy for development of cross border rail project needs to balance:

- The economic efficiency of investments
- Funding constraints and Risks
- The technical consistency within rail networks
- The transport and regional policy priorities
- Environmental considerations

A three level analysis facilitated a bottom-up approach for evaluation assessment by aggregating the multiobject agents and interdependencies of constituents as analytical described at the level of network planning, taking into account all the social values and economic conditions.

The interactions between agents and the analysis and composition of the different stakeholders perspectives lead to the business sustainability optimization, network evaluation and economic productivity optimization of a new rail cross border project.

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