

# Evolution of Macro-Modeling Practices

Subjects: Transportation

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International transport corridors (ITCs) are intricate logistical networks essential for global trade flows. The effective modeling of these corridors provides invaluable insights into optimizing the transport system. The relevance of macro-modeling in today's international transport landscape is underscored by the growing complexity of global supply chains. With the rise of e-commerce and just-in-time delivery models, the demand for strategic planning and optimization of ITCs has soared. Countries and corporations alike recognize the need for a holistic understanding of transport networks to maintain competitiveness and ensure economic growth. Macro-modeling answers this call by enabling the simulation and analysis of large-scale transport systems, providing stakeholders with a complex view of the operational intricacies and potential improvements.

Keywords: international transport corridors ; Petri nets ; macro-modeling ; logistics performance index

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## 1. Foundational Theories and Methodologies in Transport Corridors

Geographical and economic aspects: Rodrigue <sup>[1]</sup> provides foundational insights into transport systems, particularly emphasizing the geographical aspects of transportation. This research lays the groundwork for understanding the basic principles and economic significance of transport corridors in global trade.

Transport modeling techniques: The comprehensive resource offered by Ortúzar and Willumsen in <sup>[2]</sup> delves into various transport modeling techniques. This resource is pivotal for understanding the broad range of methodologies applicable to transport corridor studies.

## 2. Specific Applications and Case Studies

Belt and road initiative: Study <sup>[3]</sup> presents a network economics analysis of the Belt and Road Initiative's land corridors. It offers a unique perspective on how these corridors reshape economic centers and affect transport costs and market opportunities.

Economic perspectives in planning: Wang et al. in <sup>[4]</sup> introduce a novel planning approach for transport corridors from an economic viewpoint, focusing on travel demand and decision-making mechanisms.

## 3. Multimodal and Innovative Transport Solutions

Multimodal transport development: Kramarz et al. in <sup>[5]</sup> discuss multimodal transport, emphasizing its significance in balancing the predominance of vehicle transport within the European Community.

Advanced air mobility infrastructure: Muna et al. in <sup>[6]</sup> explore the concept of air corridors, vital for advanced air mobility, presenting insights into their efficient design and operation.

## 4. Logistics and Performance Analysis

Logistics corridors and urban growth: Boira et al. in <sup>[7]</sup> investigate the impact of the Mediterranean Railway Corridor on urban growth, highlighting the evolving relationship between rail networks and cities.

Corridor performance measurement: The corridor performance measurement and monitoring mechanism, developed by the Central Asia Regional Economic Cooperation Program <sup>[8]</sup>, provides an empirical tool for assessing goods movement efficiency in corridors, offering valuable insights for reform efforts.

## **5. Analysis of the Economic Efficiency of Transport Corridors**

Economic equilibrium in transport planning: The innovative economic equilibrium-based planning concept for optimizing transport passenger corridors is introduced in <sup>[9]</sup>. This approach employs a dynamic equilibrium analysis between supply and demand, leveraging a Gradient Descent algorithm to refine the supply structure. By targeting maximum global transportation demand and customer surplus, this model effectively reflects the economic dynamics of comprehensive transport corridors. It accounts for factors such as passenger flow, travel value, the scale rate of return, and travel time. This method demonstrates significant academic potential for optimizing passenger transportation structures, with applicability extending from regional specifics to wider urban transportation networks.

The role of corridors in economic development: Study <sup>[10]</sup> underscores the significance of transport corridors in bolstering economic growth, citing their crucial role in cultivating efficient and sustainable logistics systems. It articulates the definition of corridors as strategic links that facilitate trade, transport, and connectivity between various economic nodes. The study delineates various corridor types including development, economic, and multimodal transport corridors, and emphasizes their spatial function in connecting economic centers such as cities, ports, and industrial areas. The emphasis on multimodal transport corridors reveals their importance in the handling and transshipment of goods, highlighting their role as economic lifelines for cities and freight villages.

## **6. Policy and Regulatory Perspectives**

Management system of transport corridors: Report <sup>[11]</sup> presents an in-depth review of transport corridors, examining their functions, management structures, performance assessment, and improvement strategies, with examples including those serving land-locked developing countries. It questions the extent to which corridors can be effectively managed, given the diversity of stakeholders involved, such as government agencies, shippers, transport companies, and logistics service providers. Recognizing the complexity and variety of corridor services, stakeholders, and dependent economic activities, the report develops a typology of corridors and potential management interventions, focusing on both organizational structures and the roles of public and private sectors. The primary goal is to connect this typology with suitable management structures for specific corridor scenarios.

Trade and transport corridor management: The Trade and Transport Corridor Management Toolkit <sup>[12]</sup> consolidates knowledge on corridor project implementation, serving as a resource for policymakers and the private sector.

European transport corridor regulation: Report <sup>[13]</sup> evaluates the guidelines for the development of the trans-European transport network (TEN-T). The assessment focuses on its relevance, effectiveness, efficiency, coherence, and EU-added value, utilizing a mixed-methods approach that includes desk research, surveys, and interviews with various EU, national, and local transport stakeholders.

Evaluation of trans-European transport network: Report <sup>[14]</sup> evaluates the guidelines for the development of the trans-European transport network, providing insights into its effectiveness and areas for improvement.

## **7. Socio-Economic Impacts and Development**

Socio-economic energizers: Qaja in <sup>[15]</sup> delves into the socio-economic impacts of transport corridors, focusing on the issues they present in various regions and their effects on local and national development. The study emphasizes the vital role of roads in economic growth, facilitating the efficient transportation of people and goods, and enabling tourism development, particularly in areas with natural beauty. The research aims to explore the routes' social and economic impacts on the residents of the affected areas.

The Trans-Caspian International Transport Route (TITR): TITR is a significant rail freight transport link connecting China with the European Union (EU), passing through Central Asia, the Caucasus, Turkey, and Eastern Europe <sup>[16]</sup>. Kenderdine et al. in <sup>[17]</sup> analyze the institutional development and economic potential of the TITR from three perspectives: policy and subsidy influences, the physical and political landscape of Central Asia, the Caucasus, and Turkey, and the limited demand-side drivers from the EU. While China's policies indicate potential growth in transcontinental containerized rail transport, demand-side analysis suggests that trade development is mainly confined to enhancing regional connectivity, with limited economic justification for increased China–Europe freight movement.

Transport connections between Europe and Central Asia: A comprehensive report, funded by the EU and led by the European Bank of Reconstruction and Development <sup>[18]</sup>, evaluates sustainable transport connections between Europe and Central Asia, focusing on the five Central Asian countries and their integration into the EU's trans-European transport

network (TEN-T). The study assesses these connections using stringent sustainability criteria and proposes key actions for development, considering both enabling environments and physical infrastructure. It highlights the central trans-Caspian network as the most sustainable option for regional connectivity and economic development. The study also emphasizes the importance of detailed assessments and compliance with lending institutions' standards for each project.

Unfortunately, existing approaches to the analysis of ICTs and, especially, to their study using macro-models have a significant gap in comparison with the requirements of their rational development in modern conditions.

Existing studies primarily focus on conventional transport modeling techniques, including statistical analysis, linear programming, and simulation models. These methods are adept at handling specific types of data and scenarios but may not effectively capture the dynamic and stochastic nature of transport systems.

Many models deal with static scenarios and fail to dynamically represent the interactions and interdependencies within transport corridors, especially under varying conditions and disruptions.

Current models often overlook the complex interactions between different components of a transport corridor, such as infrastructure, vehicles, regulatory bodies, and environmental factors.

Existing approaches might not adequately address the uncertainty and variability inherent in transport corridors, particularly in international contexts with diverse regulatory, political, and economic environments.

## **8. Macro Modeling Approach to Transport Corridors**

The macro modeling approach to transport corridors, particularly in the context of international corridors with national segments, is of paramount importance for several key reasons, especially when dealing with newly developed corridors where historical data may be limited or entirely absent:

- Macro modeling is crucial in the strategic planning and development of new transport corridors. Without historical data, planners and decision-makers rely on macro modeling to simulate various scenarios, evaluate potential challenges, and foresee the economic and logistical implications of new routes. This approach allows for the assessment of feasibility, cost, and expected benefits, guiding investments, and policy decisions.
- Macro modeling can integrate various types of data, including geographical, economic, and political information. This integration is particularly valuable in international corridors, where conditions can vary significantly across national sections. The approach helps in understanding the implications of these diverse factors on the overall functionality and efficiency of the corridor.
- For new transport corridors, predicting future demand and planning capacity accordingly is challenging. Macro modeling enables planners to estimate future traffic volumes and cargo types, aiding in designing infrastructure and logistics operations that are scalable and adaptable to changing demands.
- International transport corridors require cooperation and coordination between different nations. Macro modeling provides a common framework for dialogue and negotiation, helping countries align their policies, standards, and operational procedures, which is essential for the seamless movement of goods across borders.
- Macro modeling supports economic analysis by providing insights into the potential economic benefits of new transport corridors, such as trade facilitation, regional development, and job creation. This is crucial for attracting investment and securing funding from both public and private sources.
- Macro modeling allows for adaptability and futureproofing of transport corridors. As conditions change and new data become available, the model can be updated and refined, ensuring that the corridor remains relevant and effective in meeting its long-term objectives.

Application of macro modeling is invaluable in the development and management of international transport corridors, especially when dealing with new routes lacking historical data. It provides a comprehensive, predictive, and adaptive framework essential for strategic planning, risk mitigation, and ensuring the long-term success and sustainability of these critical components of global trade infrastructure.

## **9. Justification for Macro-Modeling Approach of International Transport Corridors**

The development of international transport corridors is a complex endeavor, encompassing a vast array of variables that range from infrastructural quality to regulatory environments and logistical services. In creating a macro-model for these corridors, the challenge lies in selecting parameters that effectively encapsulate the myriad factors impacting the flow of

goods while maintaining model simplicity and usability. This section introduces the rationale behind the streamlined approach to macro-modeling, which leverages transport speed and costs as primary modeling parameters, while utilizing the World Bank's Logistics Performance Index (LPI) as a comprehensive indicator to account for the broader spectrum of logistical and procedural nuances.

This approach is underpinned by the premise that while each component of the transport chain is significant, certain key factors disproportionately influence the performance and sustainability of transport corridors. By focusing on these pivotal elements, the model aims to provide actionable insights into the performance of each national segment within the corridor, thus enabling stakeholders to make informed decisions geared toward optimization and strategic development.

The introduction of the LPI as a supplementary factor serves not only to streamline the complexity of the model but also to align it with globally recognized benchmarks of logistical efficiency. As researchers delve into the justification for this methodological choice, researchers aim to elucidate the balance struck between comprehensive detail and strategic abstraction, ensuring that the macro-model remains a robust yet flexible tool in the hands of policymakers, economists, and logistics professionals.

The proposition of using transport speed and associated costs as primary factors, supplemented by the LPI for capturing the remaining variables, can be justified as follows.

#### 1. Transport Speed and Costs as Primary Factors:

- The speed of transport directly influences the efficiency of the corridor. It reflects the operational capacity and potential bottlenecks in the movement of goods. By prioritizing speed, the model inherently accounts for infrastructural and operational constraints along the segment.
- Costs associated with transit through a corridor encapsulate a wide range of expenses, including fuel, labor, tolls, maintenance, and more. These costs are reflective of the economic conditions and the fiscal policies of the transit country, which are critical for assessing the financial feasibility of transport routes.
- Simplifying the model to focus on speed and costs allows for the creation of a predictive tool that can be more readily updated and manipulated. This approach provides a clear and straightforward framework for simulating changes in corridor operations and assessing their impact on the overall transport chain.

#### 2. LPI as a Supplementary Factor:

- The LPI, provided by the World Bank, is a comprehensive metric that evaluates six key dimensions: efficiency of the clearance process, quality of trade and transport infrastructure, ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments, and the frequency with which shipments reach consignees within the scheduled or expected delivery times.
- By incorporating the LPI into the macro-model, the complexity of logistics, including customs procedures, regulatory compliance, and service quality, is distilled into a single, quantifiable index. This allows the model to reflect these intricate processes without the need for detailed data on each aspect.
- The LPI provides a country-specific benchmark that reflects the logistical capabilities and efficiencies. This is particularly useful in a macro-model where the heterogeneity of national systems can be challenging to quantify discretely.
- Utilizing an internationally recognized index like the LPI ensures that the macro-model aligns with global standards. It also allows for comparability across different corridors and segments, facilitating benchmarking and best practice sharing.

#### 3. Practicality in Modeling:

- Speed and cost data are generally more readily available and quantifiable, making them practical primary inputs for modeling. The LPI, updated biennially, provides a regularly refreshed snapshot of logistical performance, ensuring the model remains current.
- Stakeholders can more easily interpret models based on speed and costs, which can promote broader acceptance and utilization of the model's findings. The LPI serves as an efficient way to communicate complex logistical nuances in an accessible format.
- Comprehensive modeling that individually accounts for every aspect of logistics and customs procedures would be resource-intensive and potentially less responsive to dynamic changes. The proposed macro-modeling approach provides an optimal balance between detail and agility.

## 10. Conclusions

The proposed macro modeling methodology is marked by its ability to capture and simulate the complex interactions and various states within transport corridors.

One of the most striking advantages of this proposed macro modeling methodology is its dynamic representation capabilities. By accurately modeling the transitions and delays within transport systems, it provides a more realistic portrayal of these corridors. This feature is crucial for effectively managing and optimizing the flow of goods, especially in scenarios where timing and synchronization are critical. Furthermore, the scalability of the proposed model ensures its applicability across different scales - from large, international networks to more localized, national segments. This scalability is essential in a world where transport corridors are continually evolving due to changes in trade patterns, technological advancements, and geopolitical shifts. It allows for the model to be responsive and relevant, adapting to both macro-level trends and micro-level operational details.

The proposed macro-modeling methodology represents an evolution of the state of the art for dynamic modeling of complex transport corridors. By highlighting its multifaceted impact and contributions, the conclusion can provide deeper insight into the importance of this research for both theory and practice.

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