A Multi-level Modeling Framework for Global Freight Transportation System: A logistic perspective

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1 Global freight transportation system as large complex system

The world of today is fraught with uncertainties. We can see this clearly in the ports and maritime sector, where current markets are volatile and difficult to predict, for both short and long terms. To cope with these uncertainties, port strategists and planners are developing modern, adaptive approaches that build on a deeper understanding of the many possible perturbations and their dynamic effects on port performance.

On the other hand, globalization has made our world to be connected to an extend where global systems are emerging. The interconnectedness of different actors in the global freight transportation industry has rendered such a system as a large complex system where different sub-systems are interrelated [1; 3; 5; 7] . On such a system, policy-related-exploratory analyses which have predictive capacity are difficult to perform.

Unfortunately, although there are many global simulation models for various large complex systems there is unfortunately very little research aimed to develop a global freight transportation model [1] .In the last decade a number of advances were made in freight modelling from different disciplinary angles, that have not yet been brought together in this context. This research is intended to fill this gap and produce instruments that can be the basis of new strategic information systems by first providing a clear and technically solid framework that identifies and structures all sub-systems that are relevant for the global freight transportation models.

2 Developing an integrated model of global freight transportation system

In order to be able to develop a simulation model for a large complex system mentioned above, a clear framework that is able to define, structure, and distinguish the relevant sub-systems together with the interactions therein has to first be developed. The current conceptual framework which is widely used to analyze the relationship between global trade, and freight transport is the five-layered framework (figure 1) which is developed based on 4

steps modeling approach of passenger transport [8] [11] . This framework divides freight transportation system into five layers: production, and consumption; trade; logistics, transportation and network services.

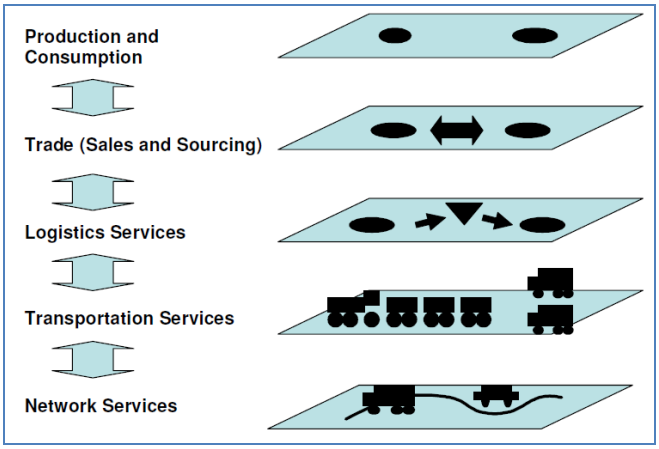

Figure 1 Multi-step freight modelling framework [8]

However, given such framework, there are two main problems that have to be addressed. Firstly, there are unfortunately not so many models which have been developed having the capability to investigate freight transportation systems in the global scale. Many of the freight models available are developed for national level [2; 4] . There are only a few models which are developed for global scale such as World Container Model [9] , Container World [6] , GloTram-2 [7] , WorldNet (http://www.worldnetproject.eu/documents/default.aspx). There are also models which are further developed for EU level using the design of SLAM such as SCENES and later on TRANSTOOL.

Secondly, there are very few models that integrates logistic dimension into the freight models developed [10] , [11] . This is a knowledge gap as logistic model plays an important function of describing the actual flows of the inter-regional freights (e.g. the structure of global logistic networks, spatial distribution of warehouses and distribution centers worldwide, etc). As such, accurate analysis on the actual routing of freight flows between production, transshipment, distribution, and consumption locations has not been made possible.

Given two problems mentioned above, we argue that a clear and detailed multi-level framework which can facilitate the development of technically sound global freight models is

needed. The presence of such framework should be able to clarify and structure the necessary sub-systems to enable the modelers to develop global models which are consistent with the 5-steps modelling aproach, technically sound, and holistic. The description of such framework is given in the following section.

3 Multi-level modeling and computation framework: a system view

The figure below presents the multi-steps modeling framework which is going to be used to first clarify the relationships between the sub-systems in the global freight transportation system. The proposed framework treats the elements of global freight transportation system as separate sub-systems which are modeled independently and it proposes the theoretical relationships between these sub-systems which are going to be implemented in the integrated model.

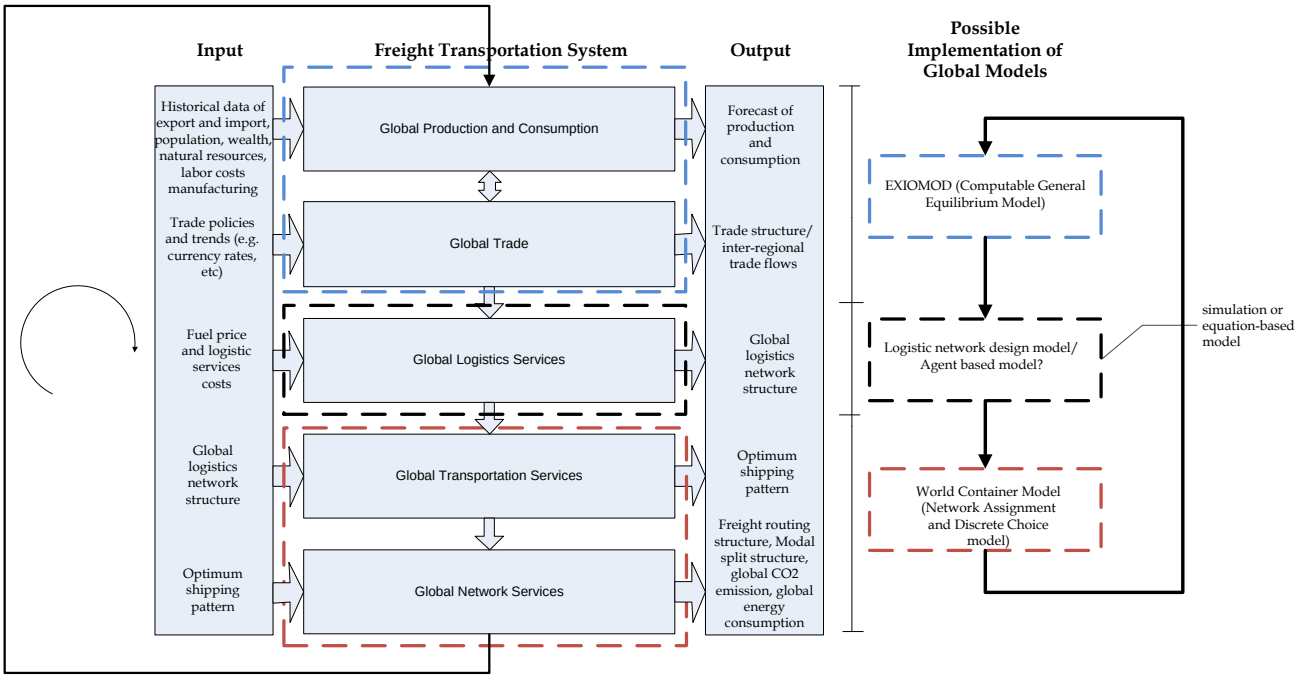

Figure 2 The Multi-level modeling framework

3.1 Computational Framework

To bring the development process one step closer to the implementation, we also propose a preliminary computational framework that adheres to the high-level multi-level modeling framework. In this case we aim to use the integrated model to devise normative recommendations to policy problems found in the global level. The framework is developed using the combination of various modeling, simulation and optimization techniques: agent based modeling, evolutionary algorithm, and freight modelling.

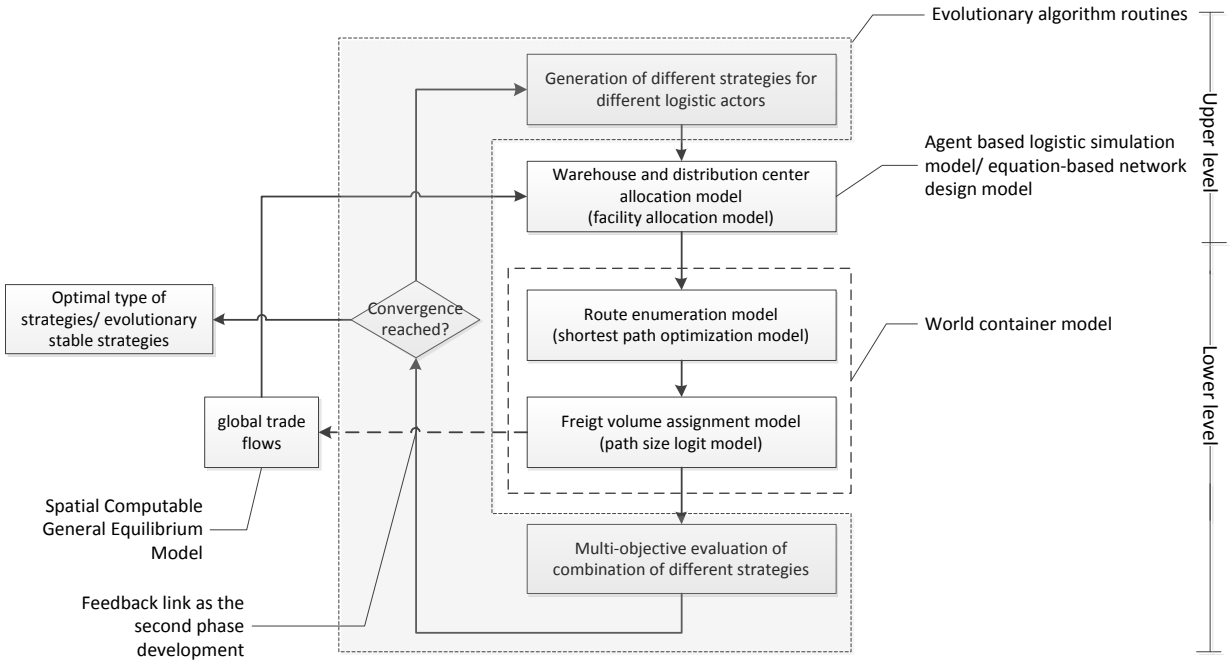

Figure 3 Computational framework

3.2 Example of projection of spatial pattern of the global freight flows in 2030

The following figure is produced by the world container model (WCM) which serves as a model that integrates the last two sub-systems [9] . This is the model that produces a graphical output of the spatial pattern of the global freight flows, with which analysis regarding the volume of freight shipped globally and its volume can be conducted. An important finding from the preliminary study is that taking into account the development of international trade, an important canal and straits such as Suez canal Malaccan strait would face a congestion problem.

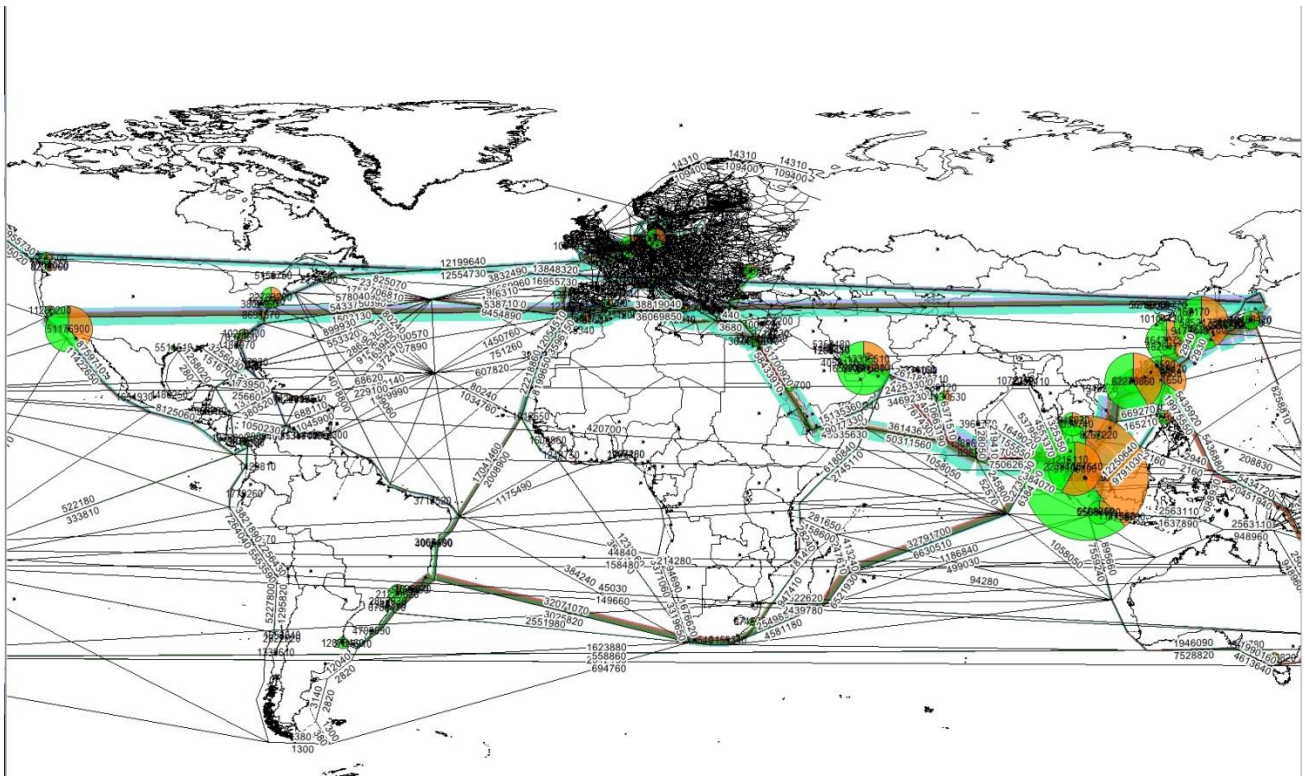

Figure 4 Global Freight flows in 2030 produced by world container model

4 Conclusion and future work

This paper has presented one of the cutting-edge developments in global freight transport modeling. The framework presented is aimed to 1) facilitate the development of a technically sound global freight tranport model which has a clear structure and solid scientific foundation. 2) make clear the feasibility of developing such global model by also putting enough attention to the scope and limitation of the model 3) to provide a clear example of the succesful application of multidisplinary knowledge in particular: discrete event simulation, optimization, and freight transport modelling techniques.

As for the future work, we will perform the implementation of the computational framework presented above using JAVA platform. Afterwards, exploratory analyses on global policy issues such as the impact of carbon pricing on spatial pattern of global freight flows would be conducted using the integrated model.

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