

The collaborative maritime transportation's problem under system dynamics and agent based modelling and simulation approaches

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Abstract

This paper deals with the collaborative maritime transportation problem which can be modeled with two different approaches: SD and ABMS, despite the existence of several methods to model problems with such characteristics. The literature indicates both methods to model systems containing large numbers of active objects (industries, people, vehicles, products) and their applications vary according to the required level of abstraction, which can consider more or less involved details. In order to contribute with the decision-making, one important logistic problem is adopted as example; and in the sequence, a **theoretic** comparative analysis between these two possible techniques to examine such problem is presented. Finally, this study describes how to model this problem using these techniques which improve the analysis of the global behavior of the supply chain, and after analysis SD method is chosen as the best appropriated method for the proposed problem and simulations are initiate.

Keywords: Collaborative transportation management. Maritime transportation. System Dynamics. Agent Based Modelling and Simulation. Decision making.

Resumo

Este artigo trata do problema de transporte marítimo colaborativo o qual pode ser abordado através de dois métodos: SD e ABMS, apesar da existência de diversos métodos para se modelar problemas com tais características. A literatura indica ambos métodos para modelar sistemas contendo grande número de objetos ativos (indústrias, pessoas, veículos, produtos) e suas aplicações variam de acordo com o nível requerido de abstração, que pode considerar mais ou menos detalhes envolvidos. De modo a contribuir com a tomada de decisão, um importante problema logístico é adotado como exemplo; e na sequência, uma análise comparativa **teórica** entre estes dois métodos possíveis para examinar tal problema é apresentada. Finalmente, este estudo descreve como modelar este problema usando tais métodos, os quais melhoram a análise do comportamento global da cadeia de suprimentos, e após análise o método SD é escolhido como o mais apropriado para modelar o problema proposto e simulações são iniciadas.

Palavras-chave: Gestão do transporte colaborativo. Transporte marítimo. System Dynamics. Agent Based Modelling and Simulation. Tomada de decisão.

1 Introduction

The understanding of logistics as the integrated planning, control, realization and monitoring of all information and products is becoming more and more dependent on technological innovations. One reason for this is the increasing complexity in combination with a high incidence of factors. Besides most of people think of complexity in terms of number components in a system or the number of combinations one must consider on making decision, dynamics complexity, in contrast, can arise even in simple systems with low combinatorial complexity. The Beer Distribution Game provides an example: complex and dysfunctional behavior arises from a very simple system whose rules can be explained in 15 minutes (STERMAN, 2000). Dynamics complexity arises from the interactions among the agents over time.

In order to support with these requirements the integration of new technologies and analysis tools has become necessary. The recently trend is the developments within Simulation techniques which are moving beyond the classical methods, propitiating a better overview of the systems, such as logistic and supply chains systems.

In these particular systems there are numerous elements and actions involved like suppliers, warehouses, trucks, ships, industries, routes and customers, not to mention all. They have been influenced by the changes generated with the globalization which highlight the companies' inability to aggregate internally all the required skills to their survival. Consequently, relationships among companies have become a forceful differential in companies' facilities, which can contribute to their success in the market.

Since taking decisions involves a complex system, companies need to create different scenarios to better analyze the behavior of the global supply chain. Thus, modelling logistic and supply chains scenarios are a challenging work but with the use of good tools it can be done. The aim of this paper is to discuss a possible way to do it (despite the existence of several methods to deal with such problem, as the development of an heuristic, mathematical programming); thus, it contains six main topics including this brief introduction. The second topic exposes one real logistical problem which is difficult to optimize but with the aid of some Simulation techniques can be better analyzed. The third topic presents a comparative analysis between the two possible techniques, System Dynamics and Agent Based Modelling and Simulation, to examine such problem and, the fourth topic comments about how to interpret the mentioned logistical problem using the concept of these techniques. The fifth topic presents an evolution in the way to model the proposed problem, by SD technique, which was chosen as the best appropriated method to simulate the behavior of the collaboration. Finally, recommendations for further studies are given at the end of the work.

2 Collaborative maritime transportation's problem

When talking about logistic several problems can be related: lay-out definition, distribution scheduling, inventory control as well as collaborative transportation and relationships polices in supply networks.

In each case the initial step to better understand the problem is the recognition of the main system's elements (industries, warehouses, suppliers and products) and their interdependences. Thus, in this topic one strategic logistic problem related to maritime transportation will be presented, which can be modeled based on SD and ABMS.

2.1 Maritime transportation in case of exportation

When deciding to export, industries shall observe the stages of the process, aiming at knowing its client market, its demands, habits and characteristics. According to Silva *et al.* (2010) it shall also define other factors like: transportation mode, specific packing for its product in order to maintain its integrity, freight form to be adopted in the negotiation, as well as the carrier to perform the transportation, besides considering the insertion of an intermediate agent (freight forwarder) or NVOCC (non vessel operator common carrier) in the negotiation.

Since most of the exportations are performed through maritime transportation, the focus in this example shall only discuss maritime exportation. Figure 1 shows the main stages of the exportation mechanism.

In maritime transportation the most important active agents are the industries, land carriers maritime carriers, maritime agency, NVOCC, load freight contractor, multimodal transport operator and cargo broker. Upon the performance of a sale or purchase it shall be established a delivery destination of the products, where the liabilities shall be shared between the vendor and the purchaser. Such liabilities comprise costs and risks on the transaction as well as accordance in the definition of deadline and volume to be transported.

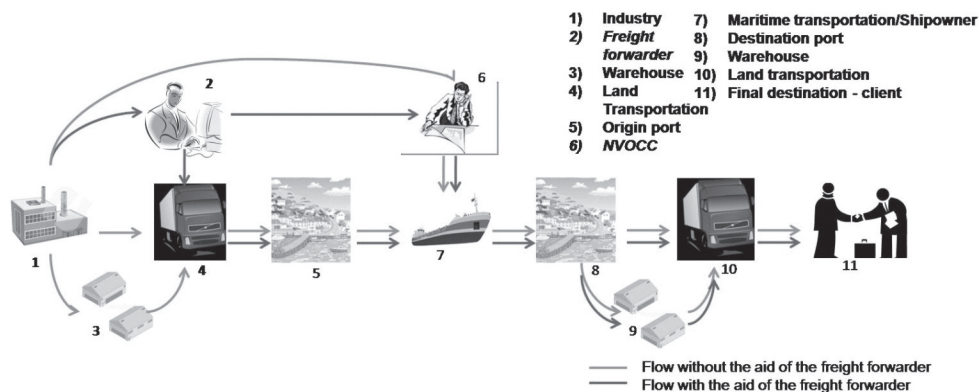


Figure 1: Stages of exportation mechanism

Source: SILVA *et al.* (2010)

2.1. 1 Transport negotiation

Normally, in case of transporting general cargo or even in pallets, the export industries or the freight forwarder shall be able to perform booking of a conventional ship in a regular line (through a NVOCC or not).

The next step is the decision of a port, as well as the terminal and shipowner/maritime carrier to be used. In the same time, shall be evaluated transportation costs, traffic time and deadline for delivering the products. One possibility to be considered is the convenience to have a safety warehouse in another city, which means, to maintain an inventory in any region to solve quickly delivery problems. As a consequence of the planned logistics it is possible to reduce the costs of transportation, inventory level in industries, loss of time on traveling and, finally, problems in the delivery and compliance with sales contract.

It is important to mention the real situation where frequently the maritime carriers decide in a Freight Conference the prices to be practiced in the maritime market. In these situations, industries acting alone do not have enough power to better negotiate with them. In situations like this, the concept of collaboration can be applied in order to create groups of industries with the same goal, negotiating with the maritime carriers in order to stop the oligopoly created by them. To a better comprehension about Collaborative Transportation, see Silva *et al.* (2009).

2.1.2 How to operate in exportation? Individually or in collaboration?

After defining the general maritime exportation mechanism, it is observed that it is very comprehensive, comprising several variables and requiring updates regarding volumes, capacity of the ships, prices, maritime fees, extras fees and law among others. One point to be discussed is how the export industries involved in this mechanism shall act: individually or in collaboration? If isolated, each exporter industry shall analyze the manner to perform the transportation of its products, considering all the stages showed in Figure 1.

Adopting collaboration concept, another possibility is searching for help from a freight forwarder who arranges such stages. If possible, this professional can join cargoes from several industries in order to achieve economies of scale in the transportation. It can be also performed directly through partnerships among export industries, without the addition of the freight forwarder.

Such partnerships are under constant transformation, altering their members to adjust to market instabilities or to expand services. They seem instable associations in a first moment, but are actually flexible and eliminate more fragile competitors, expanding the service coverage, enhance efficiency, punctuality and speed. Through this collaboration in the transport activity it is observed the formation of global logistics networks articulating productive areas, not only expanding service coverage but also frequency, efficiency and circulation rate of the products (SOUZA, 2009).

In this example, the number of involved agents and their transactions can be a limiting factor for optimization techniques. In such case, this problem can be modeled with the use of the proposed tools: SD and ABMS.

3 Simulations methods

3.1 Comparative analysis

According to Borshchev and Fillipov (2004) problems can be generally arranged on the scale with respect to the level of abstraction. Problems treated at a detailed level consider physical individual objects with exact sizes, distances and velocities. Mechatronic and control systems are located at the very bottom in Figure 2.



Figure 2: Applications of Simulation Modelling on abstraction level scale
Source: BORSHCHEV and FILLIPPOV (2004)

Factory floor models, warehouse logistics with transporters, storages are located a bit higher because start abstracting away, considering average timings, schedules, capacities and loading and unloading times, where physical movement is present sometimes. Finally, macro level traffic and transportation models may not consider individual vehicles, packets, so they use their volume. Normally, supply chains can be modeled in middle to high abstraction range. At the top of the figure are located approaches in terms of aggregate values, global feedbacks and trends.

Regarding to different approaches the major paradigm in Simulation Modelling is shown in Figure 3. SD and DES (Discrete Event Simulation) are traditional approaches, ABMS is relatively new and there is also DS (Dynamics Systems), but it is used to model and design physical systems. SD and DS deal with continuous processes whereas DES and ABMS deal with discrete time. Each approach corresponds to an abstraction level: SD has the highest abstraction level. DES is used in case of middle abstraction and ABMS is being used in all of abstraction levels, varying the nature and scale of the elements.

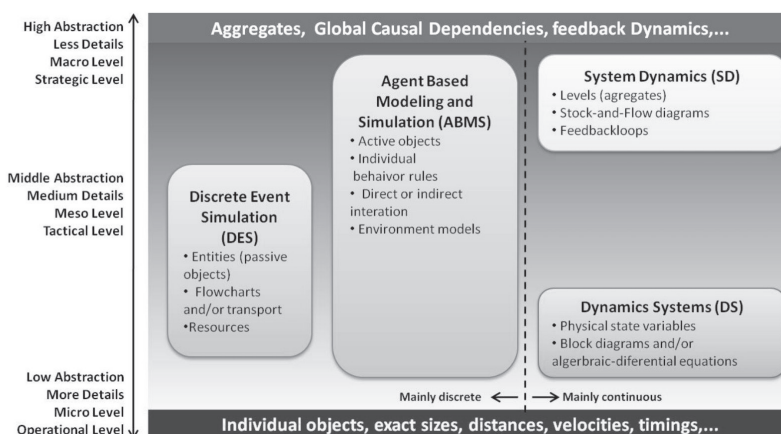


Figure 3: Approaches (paradigms) in Simulation Modelling on abstraction level scale
Source: BORSHCHEV and FILLIPPOV (2004)

Since logistic and supply chain problems involve several elements which cannot be modeled with such detail (varying from medium to high level of abstraction), the ABMS and SD approaches fit better in their analysis. Thus, in the next topics both will be better presented.

3.2 System Dynamics

System Dynamics (SD) studies the behavior of systems over time. The method was developed by Jay Forrester (Forrester, 1961) from concepts of the theory of servo-mechanisms and points to a worldview where the inter-relationships and their structures influence the systems that surround us.

System Dynamics has two fundamental languages: causal diagrams and stock-flows. Both of them allow the modeler graphically represent the system being modeled (STERMAN, 2000). In addition, they are the basis for the construction of computational models which allow simulating different policies and scenarios (LOUREIRO, 2009; MORECROFT, 2007; SANCHES, 2009).

SD is a continuous modelling and Simulation method. However, the method main differential lies in representing capacity non-linear relationships between the several system variables (STERMAN, 2000). This characteristic is extremely useful to understand patterns systems and its long-term behavior, front the adoption of different management polices and scenarios (NORTH and MACAL, 2007; SANCHES, 2009).

As consequence, SD models are aggregated and have high abstraction level (BORSCHEV and FILIPPOV, 2004). Thus, some of the methods' limitations are: the difficulty on representing detailed processes how occurs in discrete event processes; the difficulty on modelling activities with fixed duration time and the inability to model complex entities which possess characteristics of decision and heterogeny (NORTH and MACAL, 2007).

3.2 Agent Based Modelling

Agent-Based Modelling and Simulation (ABMS) is a computational method widely used to understand and analyze systems composed of many interacting individuals (NORTH and MACAL, 2007; GILBERT, 2008).

ABMS are particularly suited to support the study of topics like decentralized decision-making, local-global interactions, self-organization, emergence and effects of heterogeneity in the simulated system (AXELROD and TEFATSION, 2006; BANDINI *et al.*, 2009).

According to North and Macal (2007) the basic principle of the ABMS is: systems are larger than the simple sum of its components, in fact, the behavior of the system emerges from the interrelations between these several components. Each one of these components has its own set of rules and behaviors, which provides them the ability to affect in greater or lesser degree the system's global behavior.

In general, these components are called agents in the literature. Rocha (1999) and Bandini *et al.* (2009) warn that the notion of agent is controversial, since the term "agent" has been used by different science areas.

According to Gilbert (2008) agents are distinct parts of a computer program that are used to represent social actors as individual people, organizations such firms, or bodies such nation-states. North and Macal (2007) define agents like decision-making components in complex adaptive systems. For them an agent is an individual who has a set of attributes and behaviors and they can be defined as the heart of ABMS.

Some incipient description contemplates four important features for agents (WOOLDRIDGE and JENNINGS, 1995):

- autonomy: agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state;
- social ability: agents interact with other agents (and possibly humans) via some kind of agent-communication language;
- reactivity: agents perceive the environment (which may be the physical world, a user via a graphical user interface, a collection of other agents, the internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it;
- pro-activeness: agents do not simply act in response to their environment; they are able to exhibit goal-directed behavior by taking initiative.

Gilbert (2008) defines environment as being the simulated space where an agent is found including the physical elements and other agents. According Bandini *et al.* (2009) in the specific context of simulation the environment is typically responsible for:

- reflecting/managing the structure of the physical/social arrangement of the overall system;
- embedding, supporting regulated access to objects and parts of the system that are not modeled as agents;
- supporting agent perception and situated action;
- maintaining internal dynamics;
- defining/enforcing rules.

Unlike other paradigms or modelling methods discussed, there is lack of a universal definition for the key-concept of ABMS (SCHIERITZ and MILLING, 2003; BORSCHCHEV and FILIPPOV, 2004). For the authors this deficiency occurs in function of the diversity of science areas that use the concept of agent.

Despite its importance, Jennings, Sycara and Wooldrige (1998) argue that this definition lack does not represent a serious obstacle to progress in technique. Axelrod (2006) sees in this diversity one of the strengths of ABMS, since it allows researchers to study problems that exceed the arbitrary boundaries between their disciplines. This author presents the following arguments in favor of this perspective:

- ABMS can address certain problems that are fundamental to many disciplines;
- ABMS facilitates interdisciplinary collaboration;
- ABMS provides a useful multidisciplinary tool when the math is intractable;
- ABMS can reveal unity across disciplines.

Bonabeau (2002) identifies three benefits of ABMS over other modelling techniques. The first benefit is the ability to capture emergent phenomena. The emergent phenomena have the characteristic that make them difficult to understand and predict. In many cases they can be counterintuitive.

The other identified benefit is the ability to provide a natural description of the system. ABMS makes the model seem closer to reality. For example, it is more natural to describe how shoppers move in a supermarket than to equate the dynamics of the density of shoppers.

Finally, the third identified benefit is the modelling flexibility. ABMS can also provide a natural framework for tuning the complexity of the agents: behavior, degree of rationality, ability to learn and evolve, and rules of interactions. Another dimension of flexibility point is the ability to change levels of description and aggregation.

Like other methods ABMS has some limitations and drawbacks. The lack of consensus definitions, already discussed above, can provide a serious impediment to the method's adoption and development. One consequence of this limitation is reflected in the ABMS tools. Many of them are not user-friendly. This feature was very important for the popularization of SD method.

Since most formal theorists equate models with mathematical models, it is not surprising that some of them are hard to convince about the appropriateness and value of an Agent Based Simulation (AXELROD, 2006).

Other important method's drawback is the high computational requirements of ABMS when it comes to modelling large systems. ABMS looks at a system not at the aggregate level but at the level of its constituent units. In this case, simulating the behavior of all units can be a extremely intensive computation and therefore time consuming (BONABEAU, 2002).

3.3 Comparative analysis summary

The considerations presented above are summarized in Table 1 presented below. It is possible to identify the main differences between the methods and the integration opportunities. These opportunities are strongly connected to the methods' limitations and weaknesses.

Table 1: Main differences between the methods

	SD	ABMS
Perspective	top-down	bottom-up
Scope	strategic	all levels
Level of modelling	aggregate, macro	individual, micro
Main building block	feedback loop and stock-flows	individual agent
Origin of dynamics	levels and delays	events
Unit of analysis	structure of system	individual rules and behaviors
Structure of system	fixed	not fixed
Handing of time	continuous	discrete or continuous
Mathematical formulation	integral equations	logic
When to use	to understand patterns of transition from the system and its long-term behavior	to simulate systems that have emergent behavior, composed of interacting agents.
Main drawbacks and limitations	inability to model detailed processes and complex entities	lack of consensus definitions, many of tools are not user friendly, hard to sell, high computational requirements to modelling large systems

Source: Adapted from Loureiro (2010)

4 Practical application and outlooks

In this topic is presented in a summarized way the proposed simulation techniques applied to the maritime transportation problem.

4.1 Application of System Dynamics

When using this technique the first step is to define the system's boundary. After contacting some specialists and managers the Figure 1 (including its agents and flows) was validate and adopted for further analysis and then for this problem was realized to consider the actions of the manufactured industries and the maritime carriers. Such consideration represents a simplification of the system showed in Figure 1.

In the second step were defined the agents' objectives and the main variables which influence these objectives. The exports industries' objectives contemplate increase its competitiveness in the market and reduce logistics costs, while the maritime carriers' objectives are the reduction of offer-demand gap and the increase of its profit. These objectives can be reached based on the agents' actions like: increasing collaboration among the export industries and changes in the maritime transportation offer.

The decisions taken by the agents in the way to reach their objectives cause actions and reactions as showed in Figure 4 through the Causal Loop Diagrams. The necessity to reduce logistics costs leads the exporter industries to increase the collaboration with others. As a reaction, the increase of the bargaining power occurs which leads to the freight price decreases and consequently, logistics costs reduction. This reaction is showed in the reinforcing R1 looping.

With the export industries' logistics costs reduction the export industries increase their competitiveness in the market impacting on the exported volume. Consequently the maritime transportation demand is affected which changes the gap transportation offer-demand. This influences the freight price and also the logistics costs, according to the balancing B1 looping.

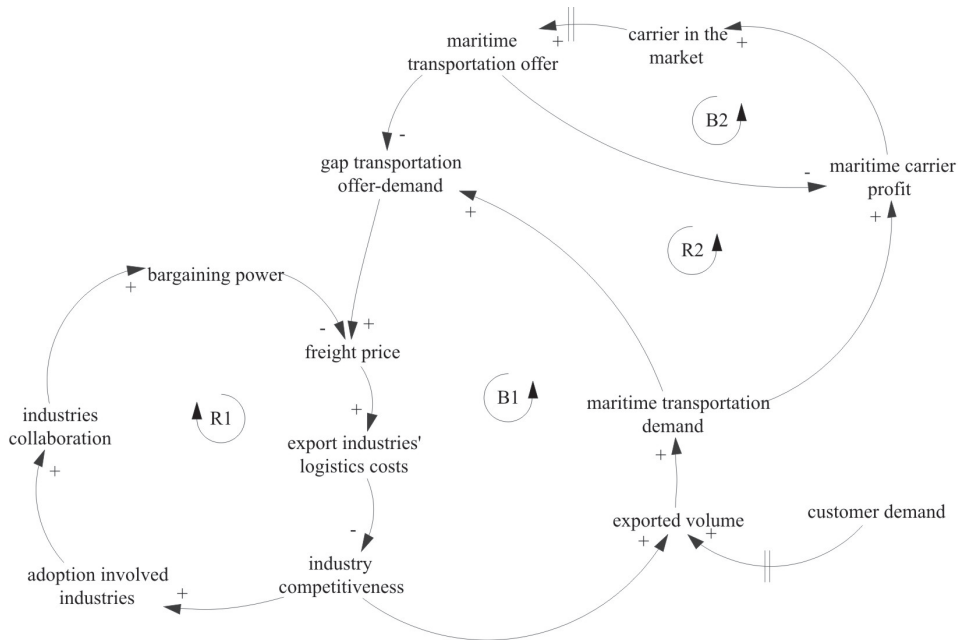


Figure 4: Reinforcing and balancing loopings between exporters and maritime carriers' negotiation

Source: the authors

The changes in the maritime transportation demand affects the maritime carrier profit, impacting the number of carriers in the market, which changes the maritime transportation offer and consequently, the gap transportation offer-demand. It is showed in the reinforcing R2 looping. Finally, in the balancing B2 looping is showed the impact in the maritime transportation offer over the maritime carrier profit.

4.2 Application of Agent Based Modelling and Simulation

As previously mentioned Agent Based Modelling does not have a set of standard for the model development and agent representation such as happen on SD method. According to Macal and North (2006) the general steps in building an agent model are the following:

1. Agents: Identify the agent types and other objects (classes) along with their attributes.
2. Environment: Define the environment where the agents will live in and interact with.
3. Agent Methods: Specify the methods by which agent's attributes are updated in response to either agent-to-agent interactions or agent's interactions with the environment.
4. Agent Interactions: Add the methods that control which agents interact, when they interact and how they interact during the simulation.
5. Implementation: Implement the agent model in computational software.

In the maritime transportation problem the main agents consist of industry, NVOCC, 3PL, maritime carrier, land carrier and customer. A convenient way of representing these agents is through a UML (Unified Modelling Language) class diagram. For example: the industry agent is represented by the following attributes: the agent's name, shipment, deadline, costs, cargo and cargo destination.

In the maritime model, the environment consists of the market where the agents negotiate the transportation. For example: an environment variable could be the offered routes and their related prices. The next step is to specify how the agent attributes are updated during the simulation in response to the agents' interactions both with the environment and/or other agents. As example, an interaction can be the choice of a maritime carrier or the choice of the route.

In the fourth step occurs the definition of the methods that control how the agents will interact. In this model at every time period must be solved the following sequence: search a partner; choose a NVOCC and/or a carrier and finally, send the shipment. The representation of the agents, their attributes and rules can be seen in the UML class diagram in Figure 5.

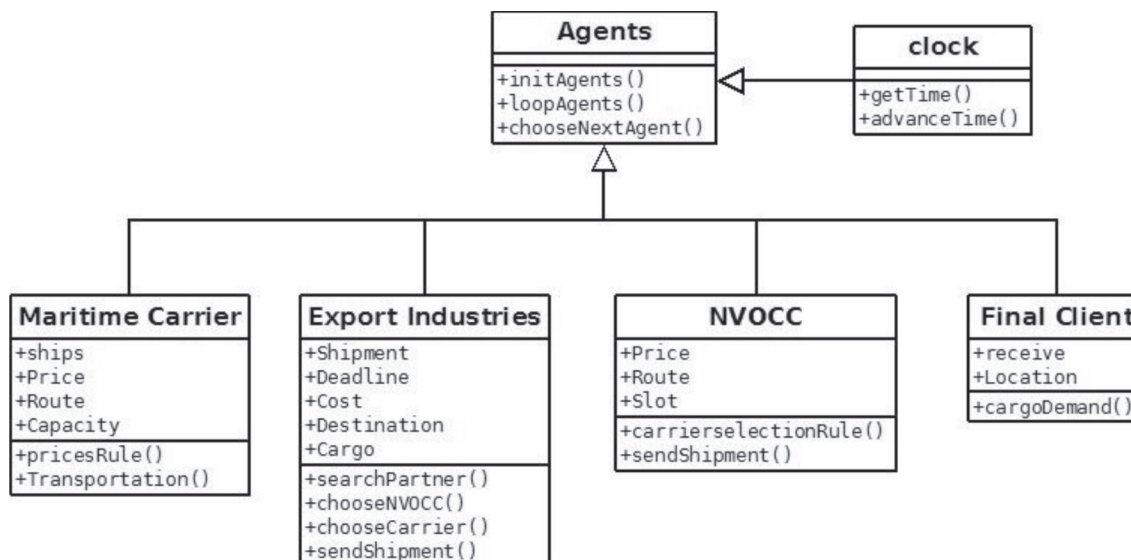


Figure 5: Agent UML class diagram

Finally, the last step contemplates the implementation of the model in an appropriated tool. There are several available modelling tools and the selection step must be done in the step ahead which was not performed in this work.

5 Modelling with System Dynamics Method

After analyzing both approaches, SD method was chosen to model the collaborative behavior between the manufactured goods' industries and maritime carriers regarding the reduction on freight costs. As was previously described, SD method is appropriated to abstract from single events and entities and to take an aggregate view concentrating on policies. To approach the problem in SD style one has to describe the system behavior as a number of interacting feedback loops, Balancing or Reinforcing.

Important things to know about SD modeling: a) as long as the model works only with aggregates, the items in that same stock are indistinguishable, they do not have individuality; b) the modeler has to think in terms of global structural dependencies and has to provide accurate quantitative data for them (BORSHCHEV and FILIPPOV, 2004).

Figure 6 presents the stock-flow diagram used to express the ships' offer-demand system. The stock of *Ships* is unique and each unit cannot be distinguished from the others and the analyses occur globally. The maritime transportation has an offer-demand system which is represented by the flows *supply* and *operation*, respectively. Both flows influence directly the stock of *Ships* and are affected by the *Freight price* practiced on the market.

The conversors *supply price scheduled* and *demand price scheduled* are modeled as a LOOK UP function (Vensim® software), containing a relation price x amount of ships; in other words, for each value adopted by *Freight price*, there is an admissible amount of ships which is affordable to the manufactured goods' industries transportation demand and, simultaneously there is an admissible amount of ships which is interesting to the maritime carriers offer in the market. Therefore, the main objective of the negotiation is to achieve the market equilibrium with a reasonable price acceptable to both (the industries and the carriers).

In such stock-flow diagram it is considered the existence of a *price change delay*; it means the *Freight price* do not change immediately but it takes some units of time (days, months) to react to changes in offer-demand. The *change in price* rate is modified by the converter *desired price*. The *desire price* is defined by the actual value of the *Freight price* and the covorsor *effect on price*. A LOOK UP function is used to define the conversor *effect on price*, expressing the variations on prices based on the inventory ratio. The *inventory ratio* is given by the *desired inventory (demand* desired inventory coverage)* and the actual amount of *Ships* in stock. So, the *effect on price* regulates *price change*. When the inventory (*Ships*) > *desired inventory* then the *inventory ratio* is > 1 and *Freight price* must be reduced. When the *inventory ratio* is < 1, *Freight price* must be increased.

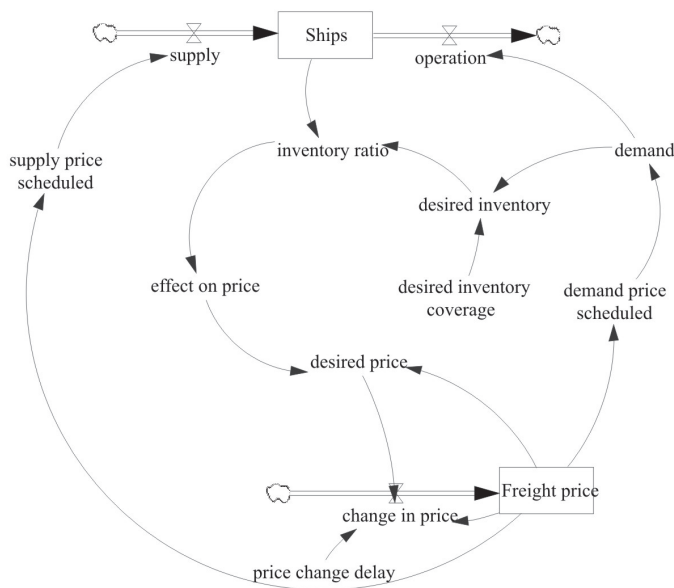


Figure 6: Stock-flow diagram for Ships' offer-demand

To exemplify a possible permitted analysis generated by the stock-flow diagram, Figure 7 shows the correlation between the *Ships* and *Freight price*. It is noted that as the *Freight price* increases, the stock of *Ships* in the market is decreased until the moment the market need more *Ships* and starts paying more for the freight, increasing the amount of *Ships* again (considering the time range is only 10 months in this application, it is not possible to see the increase in the stock of *Ships* after time 10).

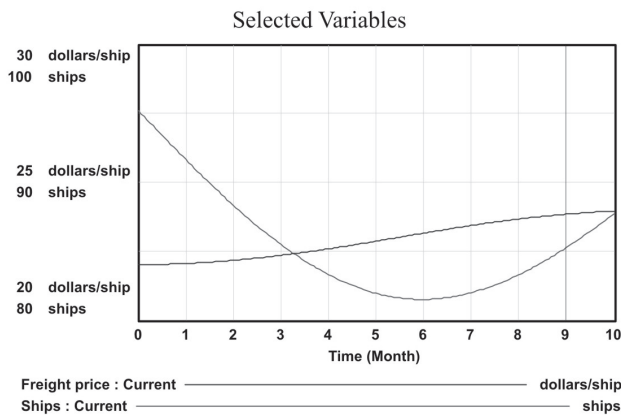


Figure 7: Correlation between Ships and Freight price by System Dynamics analysis

Figure 8 presents the stock-flow diagram expressing the industries collaboration formation. The amount of industries operating in the market is given by the stock *Industries*. The stock is modified by its inflow and outflow: *new industries attractiveness* and *collaboration abandonment*, respectively. As the number of *Industries* increases, the power bargain on freight negotiations is also increased (expressed by the convertor *power bargain effect on ships recruitment*) and vice-versa. This convertor is given by a LOOK UP function. As the *power bargain effect on ships recruitment* increases, the *cost of collaboration* reduces since is given a discount on the *freight price*.

The converter *profit ratio* measures the ration between the *cost of collaboration* and the *industry individual cost without collaboration*. This result will influence the *attractiveness effect* (LOOK UP function), which directly influences the inflow *new industries*. As the *profit ratio* increases, the attractiveness also increases and *new industries* come into the

collaboration. On the other hand, as the amount of *profit ratio* increases there is a decreasing effect in the *profit effect on abandonment* leading to an increase in the *collaboration abandonment*. It means the *Industries* will receive less profit individually if there are a large number of them in the market, discouraging them to continue in the collaboration.

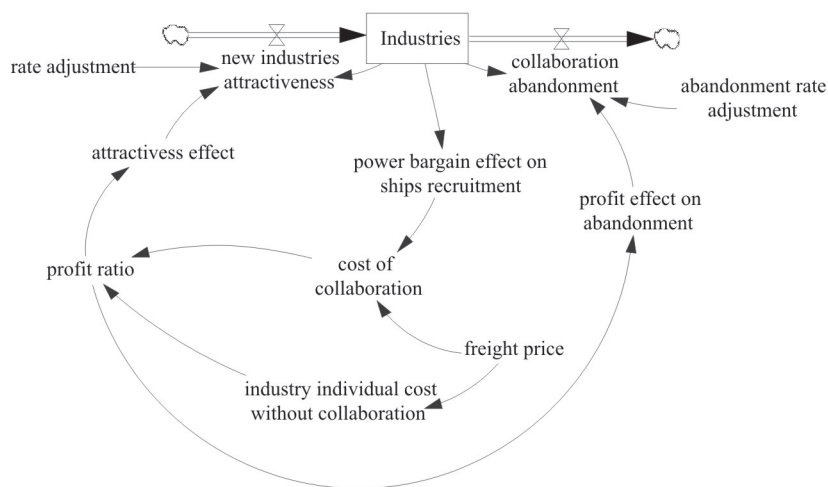


Figure 8: Stock-flow diagram for the industries collaboration formation

5.1 Comments

As mentioned previously, the aim of the diagrams construction was to clarify the understanding about the negotiations of the maritime freight prices. Thus, to initiate the construction of the stock-flow diagram for analyzing the behavior of the collaboration in the manufactured goods' exportation process, it was presented a drawing for the offer-demand system, considering as main agents the amount of *Ships* disposable in the market and the practiced *Freight price*. Such consideration was made in order to establish a growing drawing process, avoiding mistakes during the modeling process. It is quite common researchers start elaborating a complete stock-flow diagram but in the sequence, they discover failures in the model. In these cases it is easier to start a new model from the beginning then trying to fix it.

With the modeled diagram it is possible to analyze the process involving the *Ships*' offer-demand and its correlation with the *Freight price* variations. As found in the literature the offer reduces as the profits are reduced, reinforcing the proposed model. The following step in the growing drawing process was to draw the stock-flow diagram for the industries collaboration formation. With such scheme it was possible to analyze the main impressive factors in defining the behavior of the collaboration adopted by the manufactured goods' industries in the maritime transportation process.

Although the developed diagrams represent the general behavior of the maritime transportation market, the suggested results do not represent the real world negotiations due the lack of real data to take into consideration in such analysis. For this reason it is recommended to test the model considering real data practiced by manufactured goods' industries and maritime carriers, including demand data and freight prices. As an improvement of this study, it is expected to unify both diagrams in order to analyze simultaneously the behavior of the ships' offer-demand system affecting the collaboration among the manufactured goods' industries. If it shows some evidence of gains with the collaboration, it is expected to amplify the analysis considering all the other agents of the exportation process as proposed in Figure 1.

6 Conclusions and further studies

In this work the collaborative maritime transportation's problem was briefly presented, showing how the interactions among the involved agents occur. After it, some simulation techniques were selected and a comparative analysis between two of them (SD and ABMS) were done. This analysis presents the main differences, drawbacks and technical limitations.

Considering each technique has a different approach for the problem, in section 4 was presented in a summarized way two proposals for modelling the problem in study. As expected, the SD model showed an aggregate view of the problem where the borders among the different agents of the system were blurred. In this case the analysis' point of view is in the policies development, which can support the collaboration improvement and consequently, cause a change in the agents' forces and the system long-term behavior.

In the other hand, the ABMS model permits a better definition of the agents' behaviors and rules. This characteristic allows visualizing how the collaborative behavior will emerge from the interactions between the agents and between the agents and the environment.

After a comparison between them, SD method was chosen as the best appropriated method to represent the behavior of the dynamic variables enclosed in the mechanism of exportation process of manufactured goods, due its aggregate view of the problem.

Following the systematics of SD method, a causal-loop diagram was presented and as a further step in this study two stock-flow diagram were modeled, consolidating the informations and variables of the problem in analysis. The empirical findings in this study provided a new understanding of the exportation process (transportation offer-demand, freight price definition, collaboration formation) and the next step contemplates the unification of the stock-flow diagrams with all the other agents inserted in the exportation process (as in Figure 1), including real data to validate de model. Hence, sharing crucial information, believing in the CTM's partners and accomplishing the needful cultural change inside and outside the companies, it is expected to achieve excellent results in the manufactured goods' exportation process.

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