The role of collaboration through manufactured goods' exportation process under System Dynamics analysis

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Abstract: *In the recent years, there has been an increasing interest by the countries in expand their exportation volume. Although large amount of goods are exported, in some countries as Brazil, the major contribution in the exporting balance is derived from the primary goods. Thus, a possible way to increase the country's wealth is to increase the participation of added-value goods. In this context, the aim of this study is to present a new approach to analyze the behavior of the collaboration in the maritime transportation in order to reduce freight costs pertinent to the manufactured goods' exportation process. Firstly, the general exportation process is described considering the main agents involved in the logistic chain. In the sequence, two possible methods to model and analyze such problem are described (Agent Based Modeling and Simulation - ABMS and System Dynamics - SD). After a comparison between both methods, SD method is chosen as the best appropriated and its primary implementation considering causal-loop diagram is presented. As a further step, a stock-flow diagram is developed, considering the main dynamic variables included in the exportation process, permitting a better comprehension of the transportation supply-demand mechanism, freight price definition and the collaboration formation.*

Key-words: Collaborative transportation management, Manufactured goods' exportation, Maritime carriers, System Dynamic, Decision-making

1. Introduction

It is becoming increasingly difficult to ignore the logistic relative cutting-edge phase concerning the collaboration among the participants of the Supply Chain. Despite the lack of abundant scientific works, Tacla (2003) affirms that is possible to find material nominating this phase as the "logistic new wave".

The past decade has seen the fast development of collaboration among the companies in order to share their expertise and provide better results for the logistic network instead of searching for individual results (Silva *et al.* 2010). The term "collaboration" applied to logistic problems became popular with the CPFR (Collaborative Planning, Forecasting and Replenishment) approach, which is an evolution in the companies integration in order to obtain sales increase, inter-organizational alignment as well as operational and administrative efficiency (Seifert 2003).

Among its diverse applications one of them which deserves special attention is related to CTM (Collaborative Transportation Management). The CTM focuses on providing reductions in the transactions and risks' costs, enhancing the performance of service and capacity, as well as achieving a more dynamic Supply Chain (Silva *et al.*, 2009). Although there are some scientific publications about the presentation of this term (including its definition and some prototype models of implementation in some group of companies), there are few results pointing out the quantitative benefits of its application.

Therefore, the present paper, part of a thesis in development, seeks to describe a real problem existing in the exportation process in order to evaluate the collaborative action through the Supply Chain. The general exportation process involves the manufacturing industries, which need to export their manufactured goods and the maritime carriers, which offer their ships to transport goods. Before detailing the general exportation process it is worth to mention the interest in studying this problem faced to the Brazilian scenario.

In the past decade Brazil has increased its exportation volumes with exception during the 2009 world crisis, but it remains in the 24ª position with a 1.2% participation in the total world exportation volume. From the total exported volume 39.4% represent the exportation of manufactured goods and the leadership remains with primary goods (44.6%), including in majority, the exportation of grains (Secex, 2010). Considering the greater the manufactured goods exported volume the greater the enrichment of a country, it is extremely important to Brazil to increase its exportation.

Among the several existing barriers to fulfill this goal as the exigency of technical standardization and restrictions of environment nature, the maritime freight price whilst the cheapest transportation mode, is also a problem for a company when deciding to export. In most cases each industry individually negotiates the freight price with the maritime carriers and there is no bargain power involved in the negotiation; as a consequence, the system loses.

Thus, there is a gap to be explored in order to propose a reasonable manner to negotiate maritime freight prices and spread out the Brazilian exportations of manufactured goods, which is the proposal of this study.

1.1 Objective and methodology

The current study has the objective to present a new approach to analyze the role of the collaboration in the maritime transportation in order to reduce freight costs pertinent to the manufactured goods' exportation process.

In order to facilitate the reader comprehension, an initial description of a general exportation process was presented including the main involved agents in the maritime transportation chain. Considering the new proposed approach is based on the concept of collaboration among industries and carriers, a review about CTM, its definition, potential benefits and some previous results obtained by an American auto part retail chain were pointed out.

After examining the literature, System Dynamics (SD) method was chosen to properly model the problem in study due its appropriated characteristics in modelling logistic problems with a high level of abstraction, proportioning the visualization of the interrelations between the involved variables through the time. Per abstraction is understood the process of mapping the problem from the real world to its model in the world of models.

Thus, extending the causal-diagram language proposed by Silva *et al.* (2011), a preliminary stock and flow-diagram was employed in order to analyze the behavior of the collaboration in the maritime transportation process. In order to simplify the problem, only the manufactured goods' industries and the maritime carriers were considered in such model.

Although the developed model is a simplification of the real problem, the first results allowed the examination of the connection between the partner's collaboration and the bargain gains. This leads to reinforce the necessity in expanding the model, including all the other agents of the exportation process as showed in Figure 1 in order to completely evaluate the process.

2. The General Exportation Process

In order to better organize the exportation process the manufacturing industries must to know the client market, its demand, and its products' specifications and so on. In the sequence the manufacturing industries must define the transportation mode (in this study will be considered only the maritime transportation mode), the packing mode to maintain the products' integrity and the freight form to be adopted in the negotiation. It is also necessary to define a company to perform the transportation besides considering or not the support of an intermediate agent (freight forwarder) or NVOCC (Non Vessel Operator Common Carrier). Figure 1 shows shortly the stages of the exportation process adopted by Brazilian companies (Silva *et al.,* 2011).

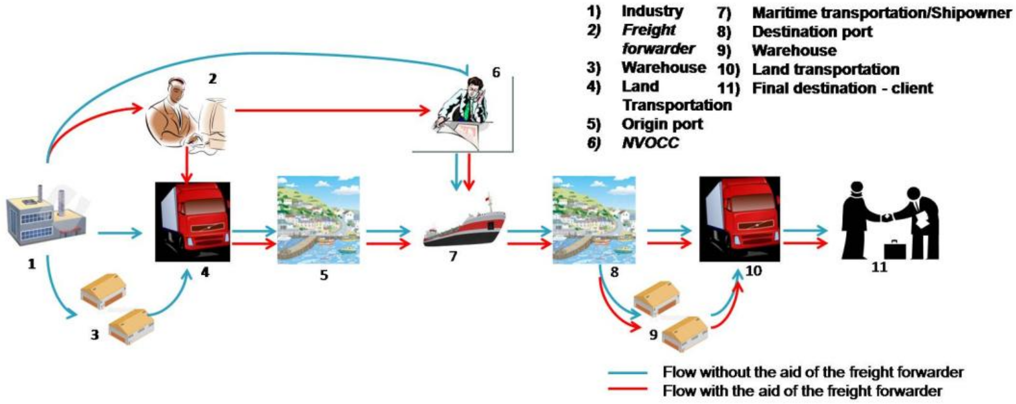

Figure 1. Stages of exportation process
Source: author

The manufacturing industries, land carriers, freight forwarder, NVOCC and shipowners are the main operating agents in the maritime transportation chain. Other agents like maritime agencies, multimodal transportation operator and cargo broker, are also influent in the maritime operation but for the purpose to simplify the problem of this study only the aforementioned agents will be considered in future analysis.

2.1 Negotiation of the maritime transportation

Following the blue flow in the Figure 1 the negotiation begins by the manufacturing industry (1) which can act alone being responsible for all the arrangement through the distribution chain. In this situation the manufacturing industry hires the land carrier (4) (in case the industry does not have its own truck fleet) to transfer the manufactured goods from the industry to the port. There is also a possibility or, in many cases, a necessity to firstly transfer the manufactured goods to a warehouse (3) to maintain a stock which can be useful to solve quick delivery problems or to retain the cargo up to the time that all the bureaucracies are solved.

The industry is also responsible for choosing the origin port to be used and at the same time it should negotiate with shipowners (7) the freight prices, choosing one of them to carry the manufactured goods. In this stage it is quite common to hire a NVOCC (6). This agent is responsible for managing several industries' maritime transportation demand in order to negotiate with shipowners the freight prices and the availability of ships to the destinations of the industries' manufactured goods.

In the destination side, there is another necessity by the manufactured industries concerning the definition of the destination port (8), which should be the most appropriated in order to deliver its goods to the clients (11). To fulfill the deliveries the manufactured industries must also hire land carriers (10) to transport its goods to intermediaries warehouses (9) or to final destinations in the destination's country.

The red flow in Figure1 is almost the same as the blue flow excepting by the fact that there is the presence of the freight forwarder (2). In this case the manufacturing industry hires this agent to be responsible for contracting and controlling all the stages in the distribution chain. It is normally a practice adopted by small and medium industries which do not have expertise in such process and then, the freight forwarder, who manages several industries' transportation demand, can be agile in the negotiation.

As a consequence of a good planning in the distributions' logistic it is possible to: reduce storage time and costs, reduce time in the course, and reduce problems in the delivery to better attend the sales contract. Regarding to the costs there are several stages of the distribution process where they can be reduced. One of them that Stopford (2009) presents as an influent key on supply and demand of maritime transportation mode is the freight prices definition.

It is worth to mention the real practice adopted by the shipowners in the freight prices formation. Normally, the shipowners define in a *Freight Conference* the prices to be practiced in the regular liner of maritime transportation. It means the conference maintain a full apparently monopoly on the trade routes. In such situation if the manufacturing industries negotiate individually the freight prices with the shipowners, they do not have bargain power to attain better prices.

This is the point where the collaboration can be applied in order to create groups of industries with the same goal, negotiating with the shipowners in order to depress the monopoly created by them and getting economies of scale as well as other benefits like major time to execute the payment of the freight and free time on shipping.

3. Comprehension about CTM

Preliminary study about CTM dates from 1993 with the introduction of the ECR (Efficient Consumer Response) concept, when the agents of the Supply Chain started working in collaboration mainly with the use of the communication networks as EDI (Electronic Data Interchange) in order to improve the flow's management from the suppliers until the consumers (Silva *et al*., 2009).

With the intention to improve the application of the collaboration, CTM concept emerged to propose a new trade concept focusing on the transportation process. Therefore, the main objective of the CTM is to reduce or to eliminate the inefficiencies occurring in the transportation process (Esper and Williams, 2003). According to the authors, *"CTM aims to develop collaborative relations among the buyers, sellers, carriers and logistic operators (3 PL's) to increase service, efficiency and costs' reductions associated with the transportation process."*

Sutherland (2003) defines that CTM starts with *"the shipment forecast, includes order generation and load tender and finally delivery execution and carrier payment. By addressing shipper, consignee and carrier inefficiencies concurrently, it becomes collaborative, with all parties benefiting."* For the author, these benefits can be achieved through direct communication between carriers and trading partners, or 3 PL execution process (as mentioned in the exportation process in Section 2, using the freight forwarder and the NVOCC).

3.1 Potential CTM benefits

Giving a step back it is worth to mention some motivators of the collaboration pointed out by several authors.

Table 1. Motivators for collaboration

Authors	Motivators
Golicic, Foggin and Mentzer (2003)	• Desired resources or capacities by other companies • Benefits' expectations • Exterior pressures by clients or competitors • Relationship history • Relationship importance • Good performance / company reliability • Strategies' alignment
Hoppe (2001)	• Need for flexibility • Efficiency earnings • Risks' reductions
Sanders e Premus (2005)	• Reduction with information costs

Source: Adapted from Sanches (2009)

As summarized in Table 1 there are several exterior conditions which lead the companies to increase the number of collaborative relationships but before companies come into collaborative chains some previous conditions should be covered. Lars (2009) presents in a quite good form such conditions. One of them and which generally first touch the companies' managers is related to the possibility of the total gains expansion (Simatupang and Sridharan, 2005). This is expected to be achieved in the maritime transportation problem faced by the manufactured goods' industries and the carriers.

As a consequence of CTM's use, companies have obtained reductions in costs' transactions and risks, increased the service and capacity performance as well as obtained a more dynamical Supply Chain. These results are obtained with operational expertise and the effective use of the *Information Technology*. The Information Technology is a quite relevant aspect to afford collaboration when permitting real time transfer data and costs and risks reductions.

For Snoo (2006) another benefit of CTM is the reduction of uncertainties in the demand and supply through an improvement in the communication and collaboration among the partners of the chain. Another benefit found in the literature concerns about the visibility of the loading status (waiting time, execution time). It facilitates the management of the carrier service when permitting pro-active actions and, thus CTM allows freight prices economies, reductions in human resources and the improvement in the service level offered to the clients.

To exemplify some quantitative gains with the use of collaboration in the transportation process, Sutherland (2003) presents a Study Case about AutoZone Inc. It is the North America's largest auto part retail chain and in 1995 it recognized that it faced many logistics challenges such as: gaining control of its inbound logistics and needing to free up working capital to fund its aggressive growth plans and did not have the logistics systems necessary to support these plans. Among the distinct results with CTM implementation, Table 2 shows some of them which generated great repercussion.

Table 2. AutoZone's results with CTM implementation

Before Re-engineering	**After Re-engineering**
Vendors controlled freight	77% of vendors converted to collect
85% LTL inbound shipments	<2% LTL inbound shipments
One week average transit time	1.5 days average transit time
No pipeline visibility	Complete pipeline visibility
Excessive freight damage	Freight damage nearly eliminated
High transportation cost	>20% transportation cost reduction
Growth constrained	Significant inventory reduction
Poor on-time performance	99%+ on-time performance
Poor utilization of private fleet	25% increase in private fleet utilization

Source: Sutherland (2003)

From Table 2 it is possible to observe that with the implementation of CTM AutoZone obtained significative results improving its performance in the market. For Sutherland (2003) the reason that there are not more success stories is that meaningful CTM benefits are not easy for shippers and carriers to achieve on their own. Developing the necessary dense network of shipper freight requires multiple shippers to combine their networks under one system and then execute collaborative transportation solutions, but this, is a question of trust (for more detailed information about “trust” in business see Lima, 2007).

A reasonably manner to simplify the required steps to build a collaborative transportation chain is given by Figure 2.

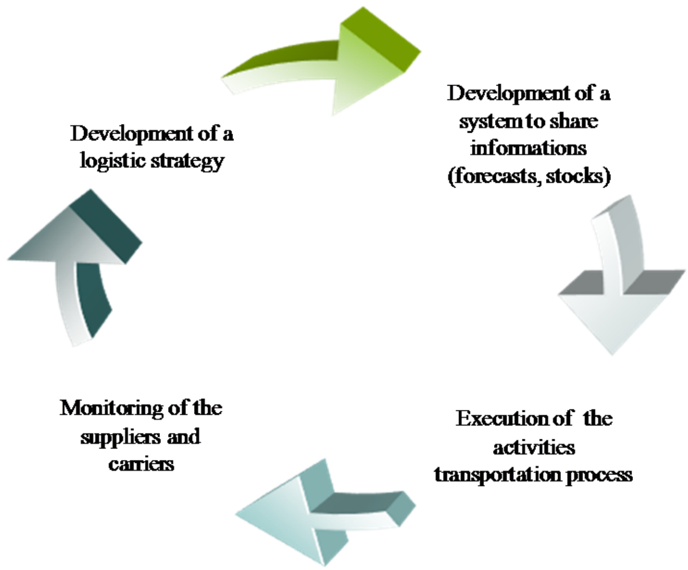

Figure 2. Steps to build a collaborative transportation chain
Source: Silva *et al.* (2009)

Initially the companies should join to the others with the purpose to elaborate a strategic logistic planning which offers gains for all the collaborators. In the sequence it is necessary to define how to deal with the communication through all the exportation process.

In possession of the required information the partners should optimize (when it is possible) or search for good solutions for the transportation chain using appropriated tools (precise or heuristic approaches, based or not in Operations Research). After defining the tools, the implementation of the technique should be done and later the monitoring assuring the obtained success persists in other negotiations. Thus, the cycle is encompassed which should be restarted all the time emerges a problem. Krajewska and Kopfer (2006) present the collaborative formation in a similar way consisting of three steps process: previous-processing, profit optimization and profit’s partition.

Although the focus of this study is not the collaboration formation it is worth to mention that still does not exist a pattern model to be followed regarding the ways to attract companies to get into a collaborative distribution chain as well as ways to reward them. To quote some studies Gomber *et al.* (1997) proposed an approach to freight expeditors with the use of several reward centers. These centers must be autonomous on the requests’ acquisition and prices negotiations but they can direct the request to other centers (partners). In Kopfer and Pankratz (1999) study it is used the groupage system which changes information and manages the capacity balance using the collaboration among the several carriers.

4. Choosing a method to deal with the study's problem

As mentioned in prior Section there is not a pattern model to be followed in order to attract companies to get into a collaborative distribution chain. In this case it is possible to extend this truth to the maritime transportation problem in the exportation chain, which still has only few published scientific studies, especially for the Brazilian scenario. So, the challenge is to find a better way to deal with this problem.

In order to determine an appropriated method to study the behavior of the collaboration in the exportation process a foregoing study was developed by Silva *et al.* (2011). In such study the methods System Dynamics (SD) and Agent Based Modelling and Simulation (ABMS) are presented due both of them are indicated to model systems containing large numbers of active objects (industries, people, vehicles, warehouses, products) and their applications vary according to the required level of abstraction, which can consider more or less involved details.

According to Borshchev and Fillippov (2004) problems can be generally arranged on the scale regarding 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 3.

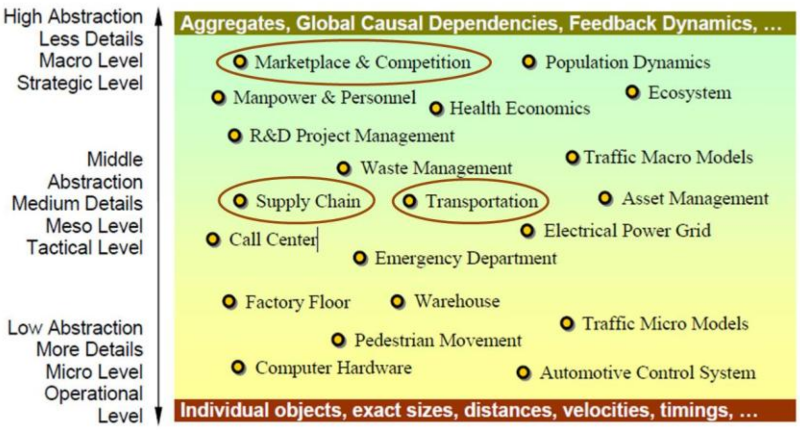

Figure 3. Applications of simulation modeling on abstraction level scale
Source: Borshchev and Fillippov (2004)

Factory floor models, warehouse logistics with transporters and 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 Figure 3 some approaches are located in terms of aggregate values, global feedbacks and trends. Following this, the collaboration formation in the exportation chain can be considered as a high abstraction problem.

For medium to high abstraction level it is indicated to model the problem using SD and ABMS. While SD deals with continuous processes and it is indicated for the highest abstraction level, ABMS deals with discrete time and it is used in all of abstraction levels, varying the nature and scale of the elements. Silva *et al.* (2011) consider that logistic and supply chain problems involve several elements which cannot be modeled with such detail (varying from medium to high level of abstraction), so the SD and ABMS approaches fit better in these problems. In Table 3 is presented the main differences between the methods.

Table 3. Main differences between the methods

	SD	**ABMS**
Perspective	top-down	bottom-up
Scope	strategic	all levels
Level of modeling	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 modeling large systems

Source: Adapted from Loureiro (2010)

4.1 System Dynamics

Developed by Forrester (1961), SD studies the behavior of systems over time, containing two fundamental languages: causal diagrams and stock-flows. Both of them allow the modeler graphically represent the system being modeled (Sterman, 2000). Moreover, the languages are the basis for the construction of computational models which allow simulating different policies and scenarios (Loureiro, 2009; Morecroft, 2007; Sanches, 2009).

Despite the capacity of SD to represent non-linear relationships among several variables it is limited to: a) represent detailed processes as occurs in Discrete Event processes; b) model activities with fixed duration time and; c) model complex entities which possess characteristics of decision and heterogeny (North and Macal, 2007). For the purpose to exemplify the SD application, Silva *et al.* (2011) presents a possible causal-diagram to model the role of collaboration in the manufactured goods' exportation process. See Figure 4.

Considering the first step when modelling with SD is to define the system's boundary, the aforementioned authors considered as agents only the manufactured goods' industries and the maritime carriers. Such consideration represents a simplification of the system showed in Figure 1. The next step was to define the objectives of the agents and the main variables which influence these objectives. The manufactured goods' industries aim to increase their competitiveness in the market and reduce logistics costs, while the maritime carriers aim to reduce the transportation supply-demand gap and to increase their profit. These objectives can be reached based on the actions of both agents: increasing collaboration among the export industries and changing the maritime transportation supply, as is showed in the Balancing and Reinforcing loopings in Figure 4.

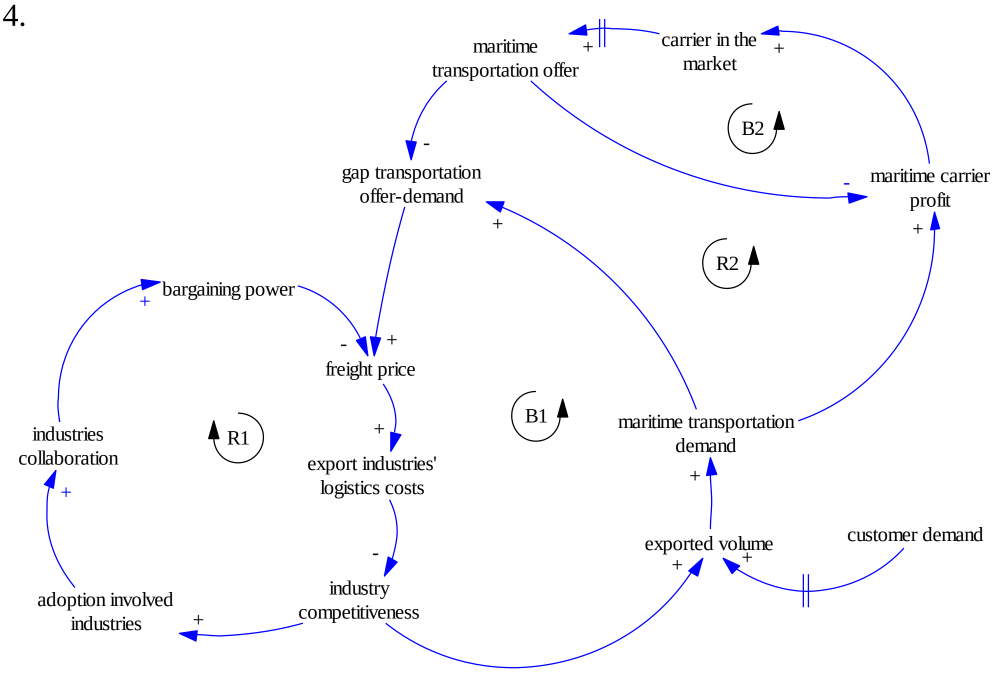

Figure 4. Reinforcing and balancing loopings between manufactured goods' exporters and maritime carriers' negotiation
Source: Silva *et al.* (2011)

4.2 Agent-based Modelling Simulation

This method is widely used to understand and analyze systems with several interacting active objects generally when there is a decentralized decision-making. The main idea of this method is to consider the interrelations among the several components of a system. In such consideration the system is greater than the simple sum of its components (North and Macal (2007). In general, these components are named *agents* and they have their own set of rules and behaviors, which provides them the ability to affect in greater or lesser degree the system's global behavior.

Some benefits of ABMS presented by Bonabeau (2002) include the ability to provide a natural description of the system in order to represent the model seem closer to reality, and its flexibility. However, as other methods ABMS presents some limitations. The lack of consensus definition by the researchers is mostly one of its limitations which provide a serious impediment to the method's adoption and development. As a consequence, many ABMS tools are not user-friendly. Another drawback is the high computational requirements of ABMS when it comes to modeling large systems.

For the purpose to exemplify the ABMS application Figure 5 (developed by Silva *et al.*, 2011) shows an UML class diagram as a possible form to model the role of collaboration in the manufactured goods' exportation process.

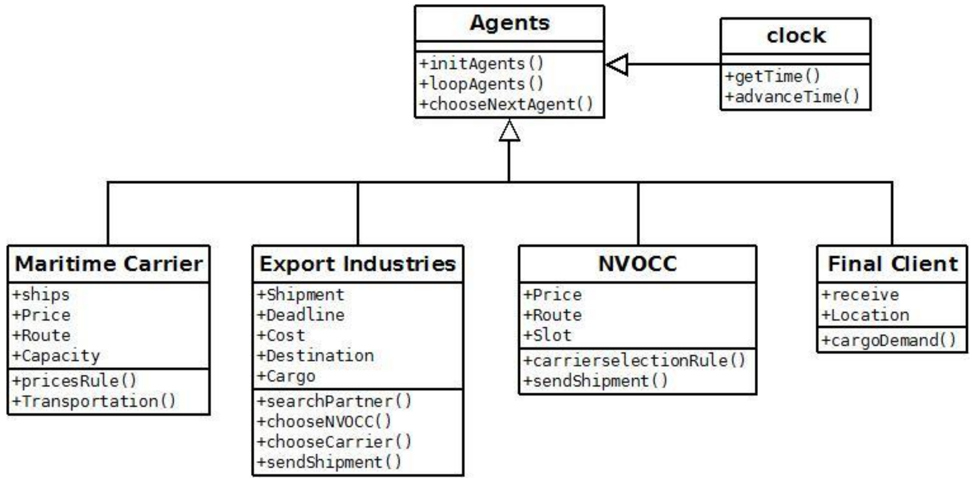

Figure 5: Agent UML class diagram
Source: Silva *et al.* (2011)

Considering there is not an ABMS pattern model to represent a system, the above diagram was built following the steps proposed by Macal and North (2006):

1. Agents: Identification of agents' types and other objects (classes) along with their attributes - industry, NVOCC, 3PL, maritime carrier, land carrier and customer.
2. Environment: Define the environment where the agents will live in and interact with - the market where the agents negotiate the transportation.
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 – 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.
4. Agent Interactions: Add the methods that control which agents interact, when they interact and how they interact during the simulation - an interaction can be the choice of a maritime carrier or the choice of the route.
5. Implementation: Implement the agent model in computational software - in such example the authors used Anylogic® software.

5. Modelling with System Dynamics method

After analyzing Silva *et al.* (2011) approach, 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' supply-demand system. The stock of S*hips* is unique and each unit cannot be distinguished from the others and the analyses occur globally. The maritime transportation has a supply-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 -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 coversor *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.

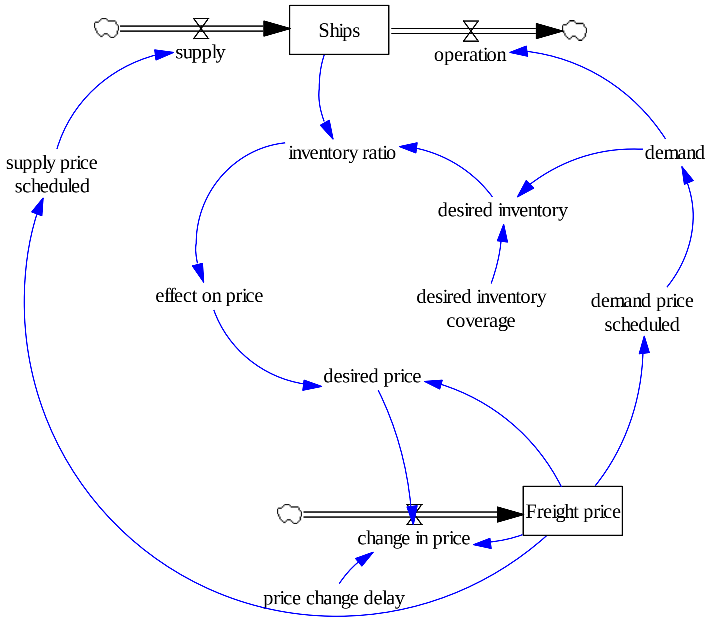

Figure 6. Stock-flow diagram for Ships' supply-demand.

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).

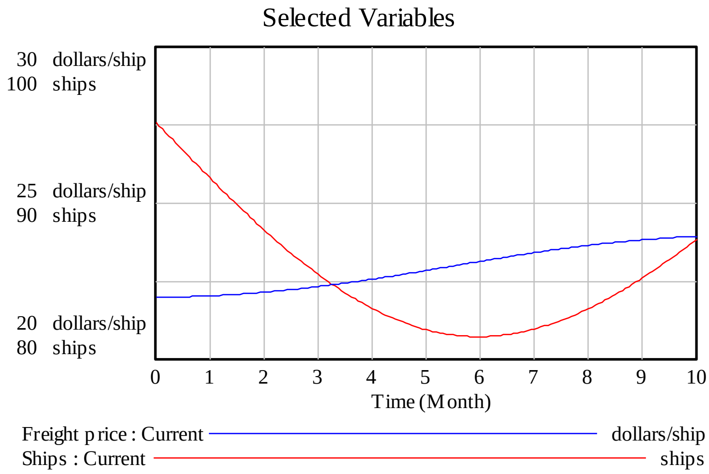

Figure 7. Correlation between *Ships* and *Freight price* by System Dynamics analysis

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 conversor *power bargain effect on ships' recruitment*) and vice-versa. This conversor 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 ratio 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.

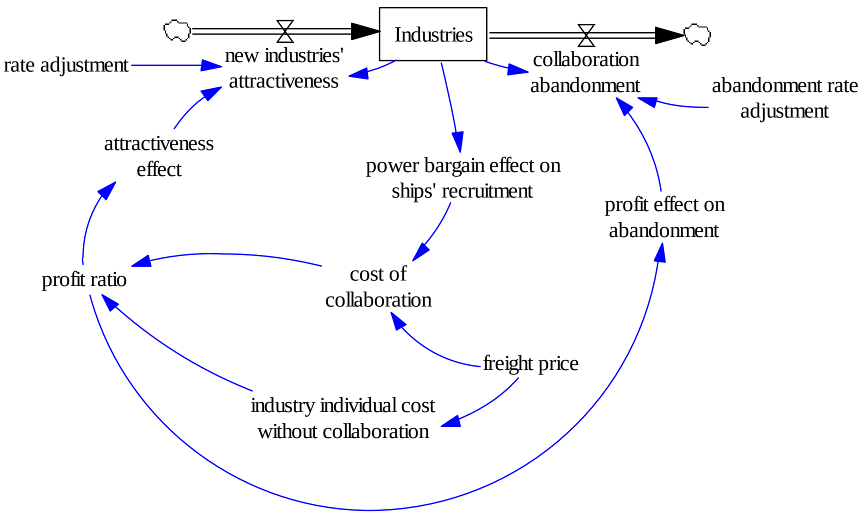

Figure 8. Stock-flow diagram for the industries' collaboration formation

5.1 Comments

As mentioned previously, the diagrams´ construction aimed to clarify the negotiation process 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 supply-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' supply-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 to 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' supply-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. Considerations

The purpose of the current study was to present a new approach to analyze the role of the collaboration in the maritime transportation in order to reduce freight costs pertinent to the manufactured goods' exportation process. In this way the main stages of the exportation process were described.

In order to define a method to model and analyze the collaboration behavior ABMS and SD were briefly described, identifying the applications and pros and cons of both. 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 by Silva *et al.* (2011) 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 supply-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 the 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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References

Bonabeau, E. 2002 "Agent-based modeling: methods and techniques for simulating human systems." Proc Natl Acad Sci U S A [S.I.] 99:3:7280-7.

Borshchev, A.; Filippov, A. 2004 "From System Dynamics and Discrete Event to Practical Agent Based Modeling: Reasons, Techniques, Tools." Paper presented at the 22nd International Conference of the System Dynamics Society, Oxford.

Esper, Terry L.; Williams, Lisa R. 2003. "The value of Collaborative Transportation Management (CTM): its relationship to CPFR and Information Technology." *Transportation Journal* 42:4.

Forrester, J. W. 1961 “*Industrial dynamics*.” Cambridge, Mass.: M.I.T. Press.

Golicic, S.; Foggin, J.; Mentzer, J. 2003. : Relationship magnitude and its role in interorganizational relationship structure.” *Journal of Business Logistics* 24:1:57-76.

Gomber, P.; Schmidt, C.; Winhardt, C. 1997 „Elektronische Märkte für die dezentrale Transportplanung.“ *Wirstschaftsinformatik* 39:2:137-145.

Hoppe, R. 2001. “Outlining a future of Supply Chain Management – Coordinated Supply Networks.” 2001. 149f. Master diss., Massachusetts Institute of Technology, Boston.

Krajewska, Marta Anna; Kopfer, Herbert. 2006. “Collaborating freight forwarding enterprises – request allocation and profit sharing.” *OR Spectrum* 28:301-317.

Kopfer, H.; Pankratz, G. 1999. „Das groupage-problem koopererender Verkehrsträger.“ *Oper. Res. Proc.*: 453-462, Springer, Berlin Heidelber New York.

Lima, Orlando F. 2007. “Logistics services performance.” Sabatical Studies Bornemouth. Bornemouth University.

Loureiro, Sérgio A. 2009. Uso integrado de metodos de simulação de eventos discretos e continuos na resolução de problems logisticos em parques de diversão. Master diss., Universidade Estadual de Campinas, Brasil.

Loureiro, Sérgio A.; Lima Júnior, Orlando F. 2010 “Integrated methods of modeling and simulation applied to operations problems: analysis and applications.” Paper presented at the XVI International Conference on Industrial Engineering and Operations Management (ICIEOM), São Carlos, Brasil.

Macal, C. M.; North, M. J. 2006. “Tutorial on agent-based modeling and simulation part 2: how to model with agents.” Paper presented at the Winter Simulation Conference, Monterey.

Morecroft, J. 2007 “Strategic Modeling and Business Dynamics: A Feedback Systems Approach.” Chichester: John Wiley & Sons.

North, M. J.; Macal, C. M. 2007 “Managing business complexity: discovering strategic solutions with agent-based modeling and simulation.” New York: Oxford University Press.

Sanches, Lars M. 2009 “Análise do acúmulo da demanda logística no final do período de comercialização: um modelo de Dinâmicas de Sistema para o setor de bens de consumo brasileiro.” PhD diss., Universidade Estadual de Campinas, Brasil.

Sanders, N. and Premus, R. 2005. “Modeling the relationship between firm IT capability, collaboration, and performance.” *Journal of Business Logistics*: 26:1:1-23.

Secex – Secretaria de Comércio Exterior. Ministério do Desenvolvimento, Indústria e Comércio Exterior. 2010. “Balança Comercial Brasileira: Dados Consolidados”. Brasília, Brasil.

Seifert, Dirk. 2003. “Collaborative planning, forecasting and replenishment: how to create a supply chain advantage.” New York: Amacom.

Silva, Vanina Macowski Durski; Coelho, Antônio S.; Zago, Camila A. 2009. “Collaborative Transportation Management (CTM): uma nova ferramenta de apoio à cadeia de suprimentos.” *Revista Tecnologia (UNIFOR)* 30:265-272.

Silva, Vanina Macowski Durski; Novaes, Antônio. G. N.; Scholz-Reiter, B.; Frazzon, Enzo M.; Coelho, Antônio. S. 2010. “Proposal of a system of collaborative transportation between manufactured export industries and maritime carriers using the concept of Autonomous Agents.” Paper presented at the XVI International Conference on Industrial Engineering and Operations Management (ICIEOM), São Carlos, Brazil.

Silva, Vanina Macowski Durski; Loureiro, Sérgio A.; Novaes, Antônio. G. N.; Scholz-Reiter, Bernd. 2011. “Kollaborativer Seetransport: Beziehungspolitik der brasilianischen Exportkette für Fertigungsprodukte.” *Industrie Management* 27:23-26.

Simatupang, T., Sridharan, R. 2005. “An integrative framework for supply chain collaboration.” *The International Journal of Logistics Management* 16:2.

Snoo, Ceel De.; Wezel, Wout V. 2006. “Simulation of collaborative planning processes – an agent oriented approach.” Paper presented at the 13th International Annual EurOMA Conference, Glasgow, United Kingdom.

Sterman, J. (2000) “Business dynamics: systems thinking and modeling for a complex world.” Boston: Irwin/McGraw-Hill.

Stopford, Martin. 2009. “Maritime Economics.” 3rd edition, London: Routledge.

Sutherland, Joel. 2003. “Collaborative transportation management – creating value trough increased transportation efficiencies.” *Business Briefing* – Pharmagenerics, September.

Tacla, Douglas. 2003. “Estudo de transporte colaborativo de cargas de grande volume, com aplicação em caso de soja e fertilizantes.” PhD. diss., Universidade Estadual de Campinas, Brasil.