Maximization of profits in import activities through a hybrid algorithm based on fictional games with multiple suppliers

Adriana Moros Daza, MSc
Industrial Engineering Department, Universidad del Norte, Barraqnuilla, Colombia
Hamburg University, IWI institute, Hamburg, Germany
amoros@uninorte.edu.co

Carlos Otero, MSc.
Industrial Engineering Department, Universidad del Norte, Barraqnuilla, Colombia
Email: cjotero@uninorte.edu.co

Carlos Paternina, PhD in Industrial Engineering,
Marketing and International Business Department, Universidad del Norte.
cpaterni@uninorte.edu.co

Abstract - An economy becomes competitive if it manages to optimize its logistics operations and to achieve a higher level of competitively is important to improve the foreign trade activities of a country. One of the most representative foreign trade activities of a country is the import activity, which ends up hindering the net gains if the adequate logistic optimization is not achieved. One way to address such optimization is through collaboration through game theory or fictional games. This article proposes a model to optimize and maximize profits of different players, taking into account the costs associated with the import of goods and scenarios with multiple suppliers eligible for the dispatch of the desired product. For this analysis, a hybrid algorithm composed of two parts is proposed, the first is responsible for determining the vendor and the international transactional conditions and the second is the solution of the fictional games. The results demonstrate that can be achieved economic benefits with the application of the model, on average the profits can be increased 22.2%, this was found after developing 100 problems with different parameters.

Keywords - Global supply chain, cooperative games, fictional games, simulation, international transport, transfer costs.

I. INTRODUCTION

Current organizations have a changing and dynamic character that is functional to their purposes and objectives. Most companies have an inventory, either raw materials or finished product. Some inventories are unavoidable, however, it is possible to minimize this inventory by improving production scheduling.

In most businesses, inventories represent a relatively high investment, which has important effects on all the main functions of the company. The inventories allow a flexibility in the operation, which without them would not exist. For example, in production companies, inventories of products in a process are an absolute necessity.

When companies manage an adequate level of inventory, it not only reduces costs, it also eliminates irregularities in the offer, it could know how much of a given item to order and when to replenish the inventory of that item.

Many companies that handle large amounts of inventory are in trouble when they must review or when they must perform operations that depend on the information it provides. So having it implies a minimum effort, but not having it implies a disaster and a great waste of time.

However, when we study global supply chains, the problem has even greater consequences, since by not having perfect information about the demand in the links of the chain, the forecasts are increasingly moving away from the real data in the first links, this is known as whip effect. This effect has a huge impact on the operational and financial costs of companies, especially those that produce goods.

For all the aforementioned, it is worth continuing to make efforts on the subject, hence the study that we wish to present is justified, which consists precisely in the analysis of global supply chains and whose objective is to formulate and validate an optimization model that minimizes the total costs in a chain of (n) retailers and (n) international suppliers. The development of the model will be carried out in two stages one for the operations between retailers and each of them with its market and another one to control the retail-supplier relations whose lead time is greater and merits planning organized according to previously established replenishment policies.

This article is divided into four sections, the first one, section II is a short literature review about the topic and the approached in the current literature. Section III is the problem description, followed by section IV with the problem and model formulation. Section V is the computational experiment and analysis of the results. Finally, the conclusions with a summary of the model and the statistic results.

II. Related Work

The studies carried out around the analysis of the supply chains are extremely extensive, however many of them are not more than representations through networks that explain the flows of materials and goods between the members of the chain. In these settings, the Game theory is a powerful tool for analyzing situations in which the decisions of multiple agents affect each agent's payoff. These agents called players are autonomous in their decision making to maximize their own utilities in a game, while other players seek the same simultaneously. A game is an iterative decision-making situation, where a possible profit is at stake. In such situation the players may decide to compete against each other, or to cooperate (forming a certain coalition), always seeking to maximize their gain. In supply chain management, Game Theory has been used as means to support the decision maker with both tactical and operational decisions, such as: capacity investment, planning production, locations problems, shipments schedules, inventory decisions among others. In the context of non-cooperative games, good surveys are provided by Cachon and Netessine (2004) and Leng and Parlar (2005), presenting a great deal of supply chain settings, concepts and a variety of interactions between supply chain partners.

In the field of cooperative games a good survey for collaboration in supply chain networks is Slikker and Nouweland (2001). The supply chain integration can be developed in several levels (Simatupang and Sridharan 2005). There are many studies at the single and multi-product level and whose models can be considered traditional or not. The former are generally based on different performance indicators as well as deterministic mathematical models, hybrid, stochastic or driven by information technology.

On the other hand, in the less traditional models we find some focused on the theory of queues and game theory, for the first case we can mention the studies of Rene Caldentey and Lawrence, who in 2002 presented a production system inventory as a row type M/M/1, called ***Make for Storing*** [1]. This study analyzed a decentralized production-storage system, in which retailers have an inventory of finished product to satisfy a demand that follows a Poisson process, and where the main purpose is to establish replacement policies for their inventories. The supplier is responsible for its level of service by controlling the capacity of the manufacturing center and behaves like the queue of a server with an exponential service time

In the case of game theory, it is relevant to mention Cachon and Zipkin [2], who worked in a supply chain of two links, whose demand was stochastic and stationary and also with fixed transport times.

In 2000, Charles Corbett [3] studied the well-known model of "Reorder Point", in a context of two players using authors-agents in the model to analyze the effects of the asymmetry in the information about the installation costs and the cost of the lost pending order. His study was key to demonstrate the way in which the traditional distribution of the decision rights to the supplier and the buyer generates inefficient results.

In 2003 Gerard Cachon and Serguei Netessine [4], published an article related to his study of "Game theory in Supply Chains analysis", in which they analyze the different applications of game theory in supply chains making a path to potential future investigations.

On the other hand, fictitious games are learning methodologies, which are modeled by an algorithm where they assume that the strategies of their opponents are randomly selected from some stationary but unknown distribution. Due to the lack of information, each player assumes from his opponent, an empirical distribution that is reflected in the history of the actions that occurs according to this distribution. This is an iterative process in which, in each cycle, players determine the best response, based on previous assumptions.

A common problem of this procedure is the lack of convergence, however, it was shown that for games with identical objectives there is convergence [5], in fact, there is a Nash equilibrium in this case [6].

In 1995, Krihsna and Sjostrom [5] demonstrated the non-convergence of the methodology in the case of mixed game strategies in which players use more than two pure strategies. Foster and Young in 1998, showed the non-convergence of the algorithm in some types of cooperative games. Meanwhile, the authors Monderer and Shapley in 1994 [7] were given the task of exploring the games that find convergence, among these, are those that have a common goal.

Since its introduction, the algorithm has undergone modifications, which have resulted in different types of fictitious games. Marco Licalzi in 1992 [8], proposes a "fictional game by cases", which extends the algorithm to situations in which players try to extrapolate information from past experiences in other similar games that have been played before in time. In 1993, Hendon et al [9], analyzed forms to define the algorithm in games in an extended way, reaching uninspiring results. Gasslt and Zafra in 1995 [10], show a form of algorithm to solve games in normal form 2x2, sum- zero and linear programming in a smaller number of iterations and with better convergence than the initial methodology. On the other hand, Washburn (2001) [11] modifies the algorithm to improve the convergence. Lambert et al. (2002) [12] present their version of the algorithm called “fictitious game by samples”, in order to optimize on a large scale. The scheme used in this article is presented in the following scheme:

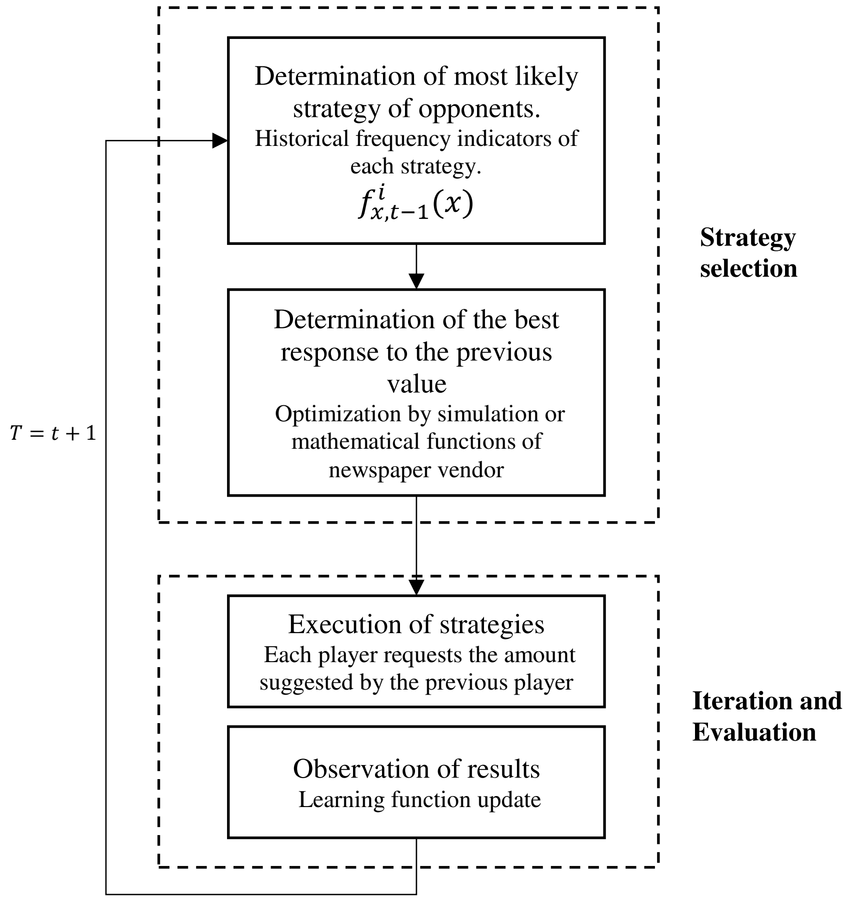

Fig.1. Fictional game algorithm scheme
Adapted from [13]

Figure 1 shows that each player chooses, in a random way, an action to take, which becomes a pure strategy. Once the strategy is established, the next step consists of establishing the action taken by the players in the following iterations based on the actions already taken by them and by a distribution associated with the behavior of the strategies used.

III. PROBLEM DESCRIPTION

The basic research of our study obeys the work done by Balza-Franco V et al (2004). Where a two-link supply chain is studied in which there are n distributors and a single supplier, common for all. The distributors have independent demands among themselves, additionally, each orders an order quantity based on the study of certain alternatives that depend on their experience and the historical compilation of the choices made in previous occasions by their competitors. In turn, each one receives an inventory but it is allowed that in case of scarcity they can redistribute it among themselves to meet the demand, in which case the transferred units become the profit of another retailer, who sells them at a salvage value that for the case study it is equal to the purchase cost. The objective is to maximize the total profits of the chain, for which the study methodology consisted of developing a model by using the theory of fictitious games and the use of a continuous solution algorithm.

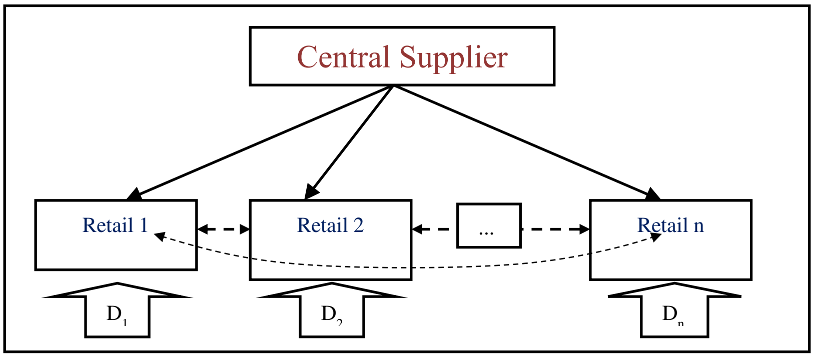

Fig.2. Dispatches scheme
Adapted from [13]

IV. PROBLEM FORMULATION

In order to extend the research carried out, it has been proposed to study an international scenario in which there are several retailers that have both local and international suppliers to whom they ask for merchandise according to their estimated demand values in order to satisfy it (Fig. 3).

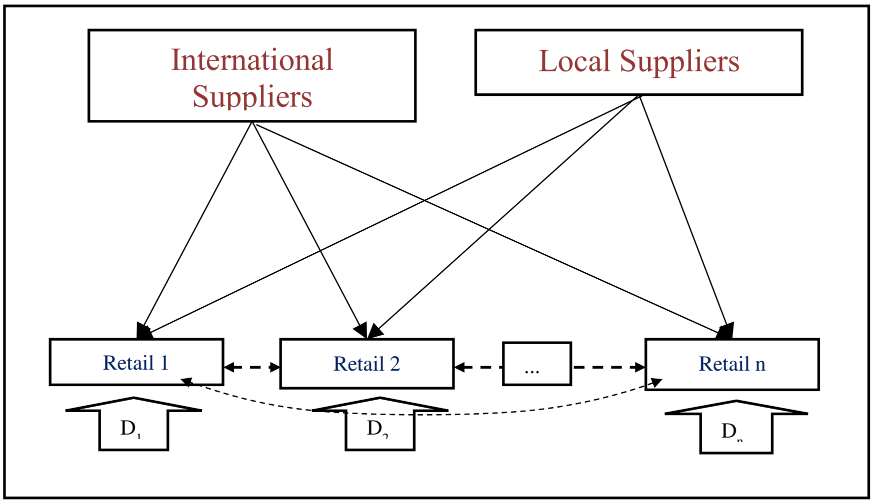

Fig.3. Dispatches scheme
Adapted from [13]

Retailers can share inventories with each other only when they have surpluses at a transfer cost equal to their purchase cost, which is the same for all retailers in the chain.

In the proposed model two order times are taken into account, one in which the inventories that are supplied with goods ordered to international suppliers are mobilized, whose lead time is assumed to be greater than the local one. And another in which the local orders are developed and daily sales among consumers, retailers, and local suppliers.

Also, the inventory costs of both, management and order, have been included in the model and a new variable corresponding to the security inventories that each retailer must have.

Next, the assumptions of the proposed model are explained:

- It is assumed that retailers are in direct contact with the market and its consumers.
- The demand of retailers is stochastic and independent among them.
- Each retailer makes its own sourcing decisions.
- Competitors can share their residual inventories with each other.
- They must make their replenishment decisions for each period before knowing the demand with the purpose of satisfying it as best as possible and minimizing order costs.
- A competitive component has been introduced so that each decision can affect the other participants in the chain.
- It is allowed to have inventory, therefore there is a cost to maintain.
- There are several international suppliers
- Only a commercial agreement will be taken into account

It is sought that the proposed model is able to select to which supplier the merchandise must be requested taking into account its cost and delivery time. This means that each retailer must find its optimal level to order xi in each period t. In case of shortages, retailers can share their residual inventories with each other at a salvage cost equal to their purchase cost.

A. Objective function

In general, the game allows to maximize the profits of the centralized system, represented by a variable (P_N^t) that depends on the demand and the actions taken by the agents in each of the phases of the game.

The profit of the centralized system (P_N^t) is obtained by the expression:

$$\max P_N^t = \sum_{i,jeN} \left(r_j - v_i - m_{ij}\right) q_{ij} + \sum_{i,jeN} (v_i) q_{ij} + \sum_{i,eN} \bar{d}\, r_i - TCI$$

Where,

$$TCI = \underbrace{\frac{Q}{2} \cdot \pi_0 \cdot h_1 + \bar{d} \cdot \bar{T} \cdot \pi_0 \cdot h_2}_{\text{averange inventory cost}} + \overbrace{A}^{\text{order cost}} \cdot \frac{\overline{D}}{Q} + \underbrace{c_Q \cdot \frac{\overline{D}}{Q}}_{\text{transport cost}} + \overbrace{\bar{I}_{ss} \cdot \pi_o \cdot h_3}^{\text{security inventory cost}}$$

The first and second terms represent the earnings for each party in the transfer phase. The first term corresponds to the perspective of the agent that receives the surplus units to supply their shortfalls. The second term corresponds to the surplus that each retailer sent to the other retailers and their recovering value of the salvage of each unit sent. The third term corresponds to the gains of the first phase of the game when the decision is made and sales are made. And, the last term represents the total international cost (TCI).

It is necessary to look for, before knowing the demand, which is the adequate amount to ask to maximize this expression, subject to:

$$\sum_{n \in N} q_{in} \leq H_i \qquad \forall i \in N \qquad (1)$$

$$\sum_{i \in N} q_{in} \leq E_n \qquad \forall n \in N \qquad (2)$$

$$q_{in} \geq 0 \qquad \forall i, n \in N \qquad (3)$$

$$x_i \geq 0 \qquad \forall i, n \in N \tag{4}$$

security inventory

$$I_{ss} = I_{ss-1} - \overline{D}$$

The restrictions of the model depend on the specific definition of the game, as are the limits on the orders (dimensions for the values of x) and the desire of the clients to be served from other points of the system (percentage of shortages that can be attended to after the first phase). The equations of the second phase make it clear that you cannot transfer more than what represent surpluses for the system (1), or of the need for units for shortages in the chain (2). The restrictions (3) and (4) ensure the sending of units and the non-negativity.

Where,

N= {1,2,…,n} : Set of retailers, where n is the number of points of sale in the system.

i, j: Sub-indices for retailers or points of sale. i,j Є N.

T: Iteration time. (In the current problem indicates days)

v_i: Salvage value of the retailer i.

r_i: Income per unit of the retailer i.

q_{ij} : Excessive units of the retailer i that take the retailer j to supply the missing parts of the latter, in the second phase of the game.

m_{ij} : Cost of transfer of units between retailer i and j.

$P_{i,t}$: Profit of the retailer i in time t

P_N^t : Total system profit

$\overline{D}$: Demand for periods (annual)

$\bar{d}$: Daily expected demand = $\overline{D}$ /365

π_0: Cost per unit

Q : Quantity of units to order

A : Cost to order per order

c_Q : Cost of international transport by order of units Q

h_1 : Cost of maintaining inventory per year per item

h_2 : Cost of maintaining inventory in transit per year per item

h_3 : Cost of maintaining excess inventory per year per item

$\bar{T}$: Lead time

H_i: Surpluses

E_n: Shortages

$\bar{I}_{ss}$: Expected security inventory

σ_d: Standard deviation of daily demand

σ_T : Lead time standard deviation of incoming orders

Figure 4 shows that based on Balza et al [13] the experiment was carried out in two phases. The first phase uses linear programming in order to determinate the international parameters of the model, like the selection of the international supplier, country of origin, quantity and transactional costs. The second phase is the fictitious game, where the best strategies and best results are obtained. The second phase is divided into two parts, the first one is the strategy selection, where the historical frequency indicators of each strategy are analyzed and selected, followed by the optimization of the previously selected value by simulation or mathematical function of the newspaper vendor. The second part of phase two is the interaction and evaluation of the responses. Where the previous strategy is evaluated and using a learning process is updated.

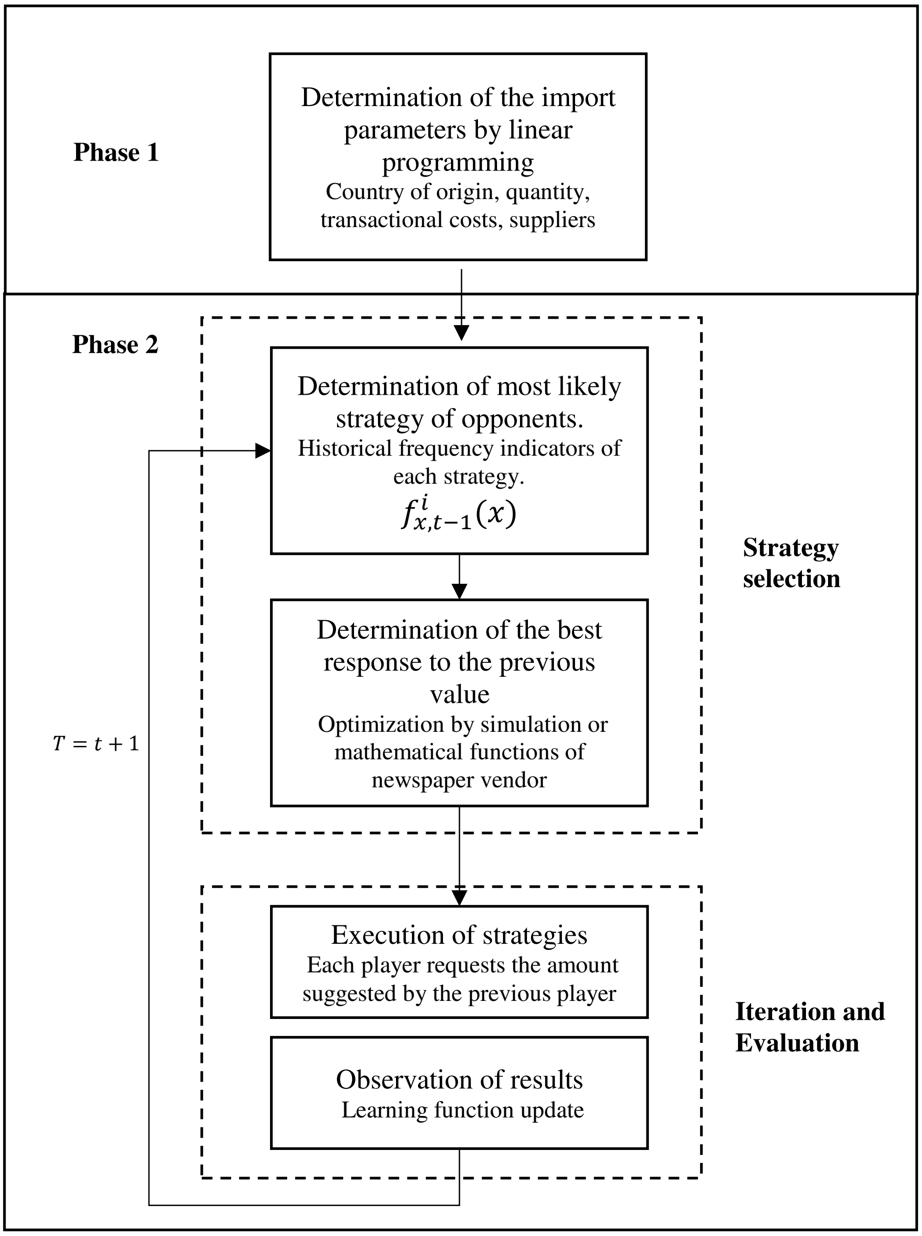

Fig.4. Algorithm scheme.
Adapted from [13]

V. Computational experiment and results

The purpose of this section is to verify the practical effectiveness of the model of fictitious games, in contrast with the strategy regularly practiced; where the players act competing among themselves and without any collaboration, however, they share the same provider. To verify this condition, 100 problems with different parameters were tested; 4 sets of retailers (4, 10, 20, 50). It was also considered the salvage value, transfer costs, demand, cost per unit, request cost, cost of maintaining inventory in a warehouse, the cost of maintaining excess inventory in transit, the cost for maintaining excess inventory, lead time in uniformly distributed intervals, which are defined in the following table:

TABLE I. SUMMARY OF THE PARAMETERS USED IN THE EXPERIMENT

Parameter	Distribution
Salvage value	~[1, 20]
Transfer cost	~[1, 100]
Demand	~[100, 1000]
Unit cost	~[5, 300]
Order cost	~[10, 100]
Cost of maintaining inventory in a warehouse	~[0.1, 10]
Cost of maintaining excess inventory in transit	~[0.1, 10]
Lead time	~[1, 30]

Now, the results obtained from this process are presented below:

TABLE II. SUMMARY OF THE OBTAINED RESULTS

Sets	Average increase	Deviation
4	8,5%	4,5
10	19,4%	6,4
20	24,6%	9,2
50	36,1%	10,4
Average	22,2%	

Table 2 shows that the model of fictitious games generates economic benefits for the participants, in no case the regular or individual model exceeded the proposed model, with a general average of 22.2%, which means that it would be expected, that Regardless of the number of players in the sets, the economic benefit is consistent. On the other hand, it was corroborated that when increasing the number of players in the group, the increase in profits is greater, the reason to think that the number of movements is increased, but the average transport costs decrease, possibly due to a greater amount of nodes available on the network.

Next, two graphs are presented with the comparative results for the samples with n = 50 and n = 10.

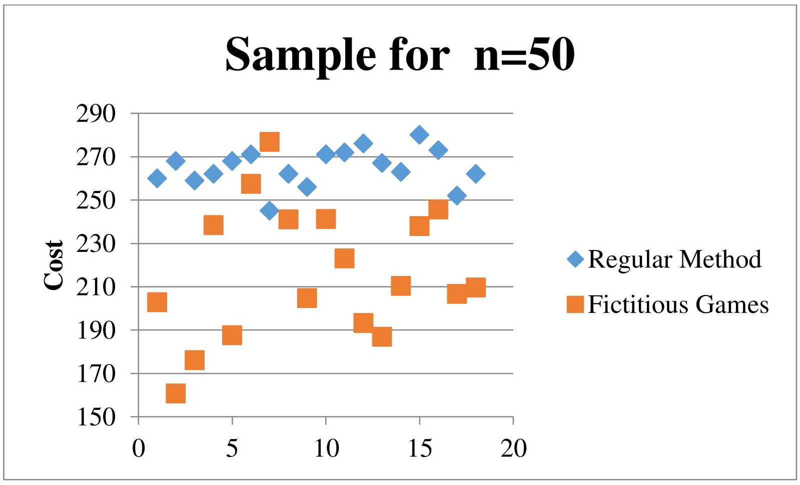

Fig.5. Results of a Sample for a n= 50

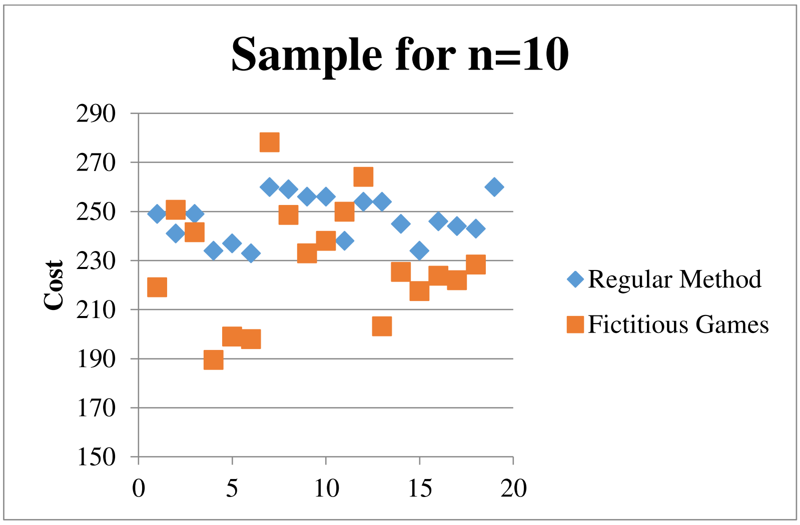

Fig.6. Results of a Sample for a n= 10

Figure 5 and 6 show that in both cases, n= 50 and n = 10, the fictitious game is in average better than the regular method, decreasing significantly the total cost. Figure 5 shows that only in one case the regular method is better than the fictitious game method. For the sample with n = 10, the situation is a little bit different than for the sample of n = 50. Figure 6 shows that for a sample with n = 10 there are more cases where the regular method is better than the fictitious one and the distance between the costs with the regular method and the costs with the fictitious game is shorter than the previous sample. This indicates that the higher n is, the use of fictitious games can improve the game and reduce more significantly the total costs.

VI. Conclusions

The model of fictitious games has a notorious application in problems of real inventories, it becomes an opportunity for the decision makers to improve the efficiency of their logistics processes. The study consisted precisely in the analysis of global supply chains and whose objective is to formulate and validate an optimization model that minimizes the total costs in a chain of (n) retailers and (n) international suppliers. The research was developed in two stages, one for the operations between retailers and each of them with its market and another one to control the retail-supplier relations whose lead time is greater and merits planning organized according to previously established replenishment policies.

The article was divided into four sections, the first section, section II was composed by a short literature review about the topic and the approached in the current literature. Section III contains the problem description, followed by section IV with the problem and model formulation. Finally, section V is the computational experiment and analysis of the model results.

The model was based on fictitious games, which have proven effectiveness to improve the operative profit when diminishing the logistic costs. The model is effective regardless of the number of players available, in fact, by increasing the number of nodes, the system increases its performance; the average reached was 22.2%, with better savings for large sets.

Cooperation between players presents important barriers despite showing economic benefits [14]. Apparently, the distrust between the parties, turns out to be the biggest barrier, so the biggest difficulty seems to be the formation of large coalitions.

The solution of the model is composed of two fundamental parts; the first consists in determining the suppliers to be employed, considering those parameters of international transactions, and the second the design of the network of fictitious games. It is recognized then, the possibility of locality of the solutions, and not the global, in spite of that the model shows favorable results. It is noteworthy that the model is tactical, so its implementation may involve changes in rates.

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BIOGRAPHY

Adriana Moros Daza is an Industrial Engineer from Universidad del Norte. She holds a Master in Industrial Engineering from the same university. Currently, she is a Phd in Industrial Engineering Student in Universidad del Norte, Barranquilla, Colombia and a PhD in Business Adminitration student in the University of Hamburg, Hamburg, Germany. Ms Moros is an Associate Professor of the Department of Industrial Engineerng at the Universidad del Norte, Barranquilla, Colombia. Ms Moros have done research projects with the University in the region, like project Logistics and Caribbean ports program – LOGPORT, the development of a business management platform to coordinate administrative processes in schools and the development of a logistic supply chain for new bio products of the region. She has also worked with the Transport Ministry of Colombia in projects related with the optimization of the last mile and the development of cargo brokers. Her research include supply chain management, simulation, optimization, port logistics, port community systems for underdeveloped countries, and collaboration in supply chain.

Carlos Otero is assistant professor of the Industrial Engineering Department at Universidad del Norte, in Barranquilla, Colombia. He holds bachelor and master degree in Industrial Engineering from Universidad del Norte. He is Ph.D. student of Industrial Engineering from the same University, his research focuses on Supply Chain topics related to management systems, collaboration in logistics, supply chain finances, modeling and optimization. Mr Otero have done research projects with the University in the region, like project Logistics and Caribbean ports program – LOGPORT and the development of the logistic network of the Palma tries.

Carlos D. Paternina-Arboleda is an Industrial Engineer from Universidad del Norte. He holds a Master in Industrial Engineering and a PhD in Industrial Engineering, University of South Florida. He is an Informs Member. Professor Paternina-Arboleda is an Industrial Entrepreneur. Director or the Innovation in Logistics and Caribbean ports program – LOGPORT. Co-Author of books: "Modelos de planificación cooperativa de recursos energéticos", "Simulación de sistemas productivos con arena", "Manual Práctico para Gestión Logística.". Author and co-author of 50+ technical papers in scientific journals. Member of the Executive board of "Comisión Regional de Competitividad del Atlántico", and the executive board of the "mesa sectorial de transporte fluvial del SENA".