A DYNAMIC VIEWPOINT TO PLASTIC-SUPPLY CHAIN MANAGEMENT IN COLOMBIA

UN PUNTO DE VISTA DINÁMICO PARA LA GESTIÓN DE LA CADENA DE SUMINISTRO DE PLÁSTICO EN COLOMBIA

UMA VISÃO DINÂMICA PARA A GESTÃO DA CADEIA DE PLÁSTICO DE ABASTECIMENTO NA COLÔMBIA

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Abstract

Since plastic is considered an essential raw material for the production of several products, there is the opportunity to analyze the dynamic behavior of the supply chain management in Colombia. This paper argues that strategic modeling is an important measure to build confidence in a simulation model regardless of validity test. In order to analyze the main variables of the supply chain, the article shows a dynamic viewpoint to understand the relationship between the players. The aim of this paper is to explore and discuss the plastic-supply chain structure, and the guidelines for the strategic modeling through a stock-and-flow diagram of a system dynamics model. The major finding of this paper consists in an overview of the strategic modeling and drivers of a system dynamics model in supply chain management.

Keywords: system dynamics model, modeling, supply chain management, petrochemical sector.

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Resumen
Desde que el plástico es considerado materia prima esencial para la fabricación de diferentes productos, existe la oportunidad de analizar el comportamiento dinámico de la gestión de la cadena de suministro en Colombia. Este artículo argumenta que el diseño estratégico es una medida importante para crear confianza en un modelo de simulación, sin considerar una prueba de validez. Con el fin de analizar las principales variables de la cadena de suministro, el artículo muestra una visión dinámica para entender la relación entre los actores. El objetivo de este artículo es explorar y discutir la estructura de cadena de suministro del plástico, así como también las directrices para el diseño estratégico a través del diagrama de flujo y abastecimiento de un modelo dinámico de sistema. El mayor resultado de este artículo consiste en un resumen sobre el diseño estratégico y los impulsores de un modelo dinámico de sistema en la gestión de la cadena de suministro.

Palabras clave: modelo dinámico del sistema, diseño, gestión de la cadena de suministro, sector petroquímico.

Resumo
Dado que o plástico é uma matéria prima essencial para a produção de diversos produtos, existe a possibilidade de analisar o comportamento dinâmico da gestão da corrente de abastecimento na Colômbia. Este artigo expõe a modelagem estratégica como uma importante medida para construir confiança num modelo de simulação sem importar as provas de validade. Para analisar as principais variáveis da corrente de abastecimentos, o artigo expõe um ponto de vista dinâmico para compreender a relação entre os participantes. O objectivo deste artigo é explorar e discutir a estrutura da corrente de abastecimento de plástico, e os alineamentos para a modelagem estratégica através de um diagrama de existências e fluxos correspondente a um sistema de modelagem dinâmica. O maior achado deste artigo consiste numa descrição da modelagem estratégica e drivers de um modelo de sistema dinâmico na gestão da corrente de abastecimentos.

Palavras-chave: modelo de sistema dinâmico, modelagem, gestão de corrente de abastecimentos, sector petroquímico.

INTRODUCTION

An overview of the different approaches aimed at the supply chain management showed that this is growing. The supply chain management is a complex process and requires a strategic approach aimed at multiple actors and hierarchical levels. A dynamic viewpoint of the supply chain and their relationship between players allows a strategic approach to policies design and an improved performance (Herrera Ramírez, 2012), many models can be used in order to test the viability of policies. However, system dynamics modeling is useful for this purpose. System dynamics modeling is an approach to analyze the temporal and dynamics behavior of complex enterprise systems, which might require a strategic modeling, it is also well suited to understand complex feedback structures within the supply chain. This allows a quantitative analysis of the variables that affect the supply chain management, as well as it provides a valuable media to understand the productivity and efficiency of the production process (Miesing, Krzykowski & Rich, 2010). The supply chain literature has identified several problems related to management (Power, 2005). Musango (2013) remarked the necessity of improving the plastic supply chain using a more sustainable intervention policy. Therefore, system dynamics modeling involves the formulation of sustainable policies based on the relationship between the players of the supply chain.

By focusing on the dynamics of the supply chain, this study addresses this research by assessing the collaboration and integration between the stakeholders. However, despite the fact that various collaborative approaches tend to discuss the integration through information technology, it has not been possible to take into account the behavior over time of the recollected information and material flow. This article is motivated by the need of a strategic modeling that would assist the decision-making process. The drivers of the plastic-supply chain are identified in this structure of simulation model regarding to system dynamics methodology.

The aim of this article is based on the conceptual framework of supply chain management. These first conceptual findings are discussed. The arguments in the article show how integration strategies allow the coordination of the supply chain. This paper gives consideration to both material and information flow of the supply chain. In the history of logistics, the coordination between players has been thought of as a key factor in the supply chain management. This study evaluates the dynamic of the plastic-supply chain in Colombia and strategic variables that can be applied to it.

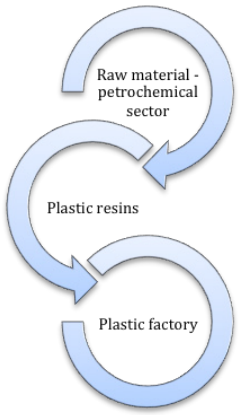
The article has been organized in the following way: first, the study investigates the dynamic structure of the plastic-supply chain in Colombia; in second place, we explore the background literature of supply chain management and system dynamics modeling, the next section proposes a strategic modeling and drivers of a system dynamics model in the plastic-supply chain. Finally, this paper concludes and suggests a future research for the field of supply chain management and system dynamics modeling.

BACKGROUND: PLASTIC-SUPPLY CHAIN MANAGEMENT

Department of National Planning - DNP (2004) reported a study made in Colombia about the plastic-supply chain structure. The results of this study indicate that the export of polyvinyl chloride (PVC) increases over time. The polyvinyl chloride is the most used thermoplastic polymer in the plastic-industry. The PVC is used in a variety of products (e.g. consumer products, raw and construction materials), so the development of plastic-industry shows an increase.

Figure 2 presents the plastic-supply chain structure in Colombia, which is composed of three basic segments: raw material suppliers, plastic resins and manufacturing. The petrochemical sector has important measures about the environmental impact control of the raw material used. In this sense, financial measures could be adopted to provide an investment incentive, which allows to apply environmental control measures (Toro, Requena & Zamorano, 2010).

Figure 1. Plastic-supply chain structure



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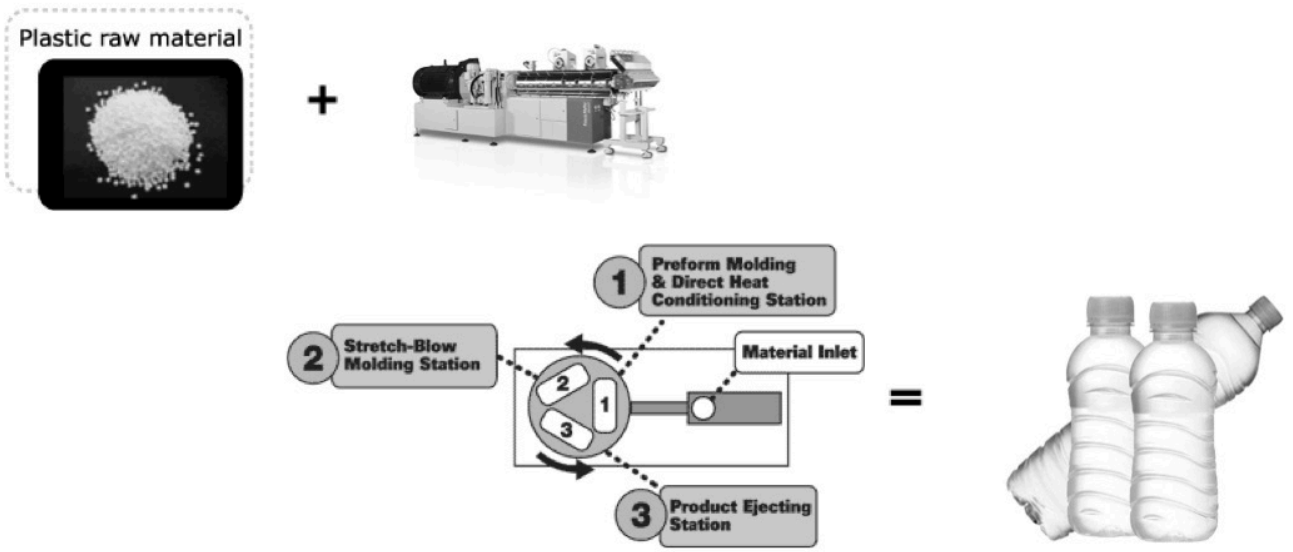
Since 2003, in Colombia there has been a steady increase in the amount of plastic exports. The petrochemical sectors share an investment net in manufacturing. However, it can increase the oil price that would limit the growth of this sector. The plastic factories grow with a major number of products and low-prices, which is an important option for the development of the players inside the supply chain. Some of the most important technical aspects in the manufacturing systems for plastic products are the selected technologies. Figure 2 shows the process of plastic products and the relationship between plastic as a raw material and the technologies used to process it.

Figure 2. Plastic products manufacturing



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Another important factor that affects the plastic-supply chain structure includes closed-loop feedback of information and material flow. An efficient supply chain design requires of a strategic modeling that allows us to understand the relationship between stakeholders and the wide distribution network.

SUPPLY CHAIN MANAGEMENT AND SYSTEM DYNAMICS MODELING

In the 1950s, Jay Forrester studied some of the ways on which the supply chain is analyzed. Also, Forrester (1961) applied his analysis to various business and strategy problems. Although system dynamics modeling has been applied to strategy problems, many studies have studied supply chain from different approaches (e.g., linear programming). The system's behavior allows us to understand the dynamic relationship and information flows between the players of the supply chains (Herrera & Orjuela, 2014). This methodology was developed to model and simulate policies of complex enterprise systems. In this sense, system dynamics is a methodology used to give a better understanding of the supply chain management. System dynamics has been used to understand and learn process of complex enterprise system (Cosenz & Noto, 2016). According to Cosenz (2014) the system dynamics modeling can be aimed to interpret phenomena and analyze the dynamic complexity of social systems and organizational performance, while also giving a broader view in terms of time horizon.

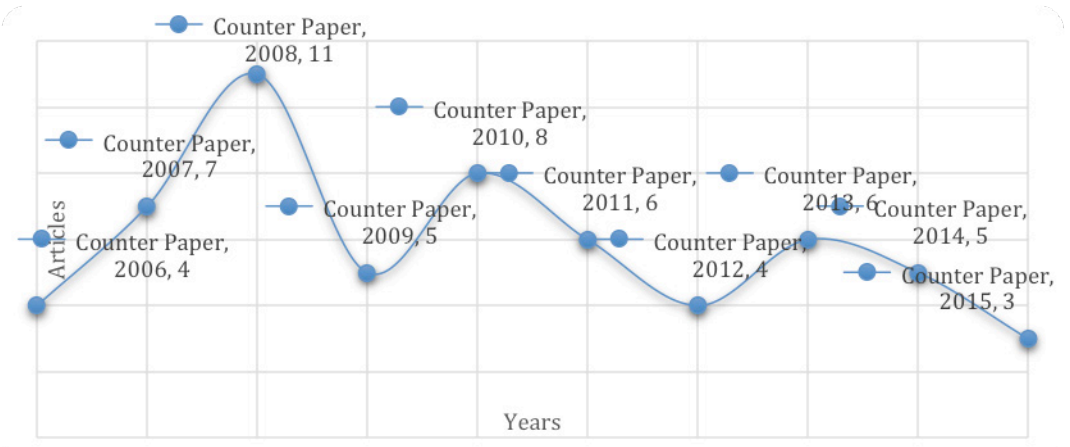
The behavior of the system depends on the supply chain structure and its relationships between the stakeholders (Niu, 2008). The bad information is a

cause of the bullwhip effect in the plastic-supply chain. The bullwhip effect involves a small change at one end of the supply chain that can cause bigger changes for the others. However, this effect can be reduced significantly by producing an information exchange between the partners of the supply chain. In this context, Yasarcan (2011) argued that sharing information and coordination between stakeholders should reduce the bullwhip effect.

System dynamics modeling allows representing a continuous flow of inventory throughout closed-loop supply chain. Poles and Cheong (2009) proposed a system dynamics model for inventory management in closed-loop supply chain. This study has identified various factors that affect the recovery process of the product used and its effects on inventory management. Others studies examine the impact of ecological motivation and technological innovation on closed-loop supply chain (Georgiadis & Besiou, 2008).

In this way, plastic-supply chain integration between stakeholders as a management strategy is needed. Despite the importance of studying the integrated approach of the supply chain management, few articles address the strategy modeling. Figure 3 presents the dynamic of the literature reviewed in the integrated approach of the supply chain management. Several studies investigating integration effect have been carried out on supply chain (Power, 2005; Petersen, Handfield & Ragatz, 2005; Flynn, Huo & Zhao, 2010; Cousins & Menguc, 2006; van der Vaart & van Donk, 2008; Wiengarten & Longoni, 2015). These studies show information about technological approaches on the supply chain as an integration strategy (Gunasekaran & Ngai, 2004; Devaraj, Krajewski & Wei, 2007; Zhao, Huo, Flynn & Yeung, 2008).

Figure 3. Dynamic of the articles in supply chain management integrated approach



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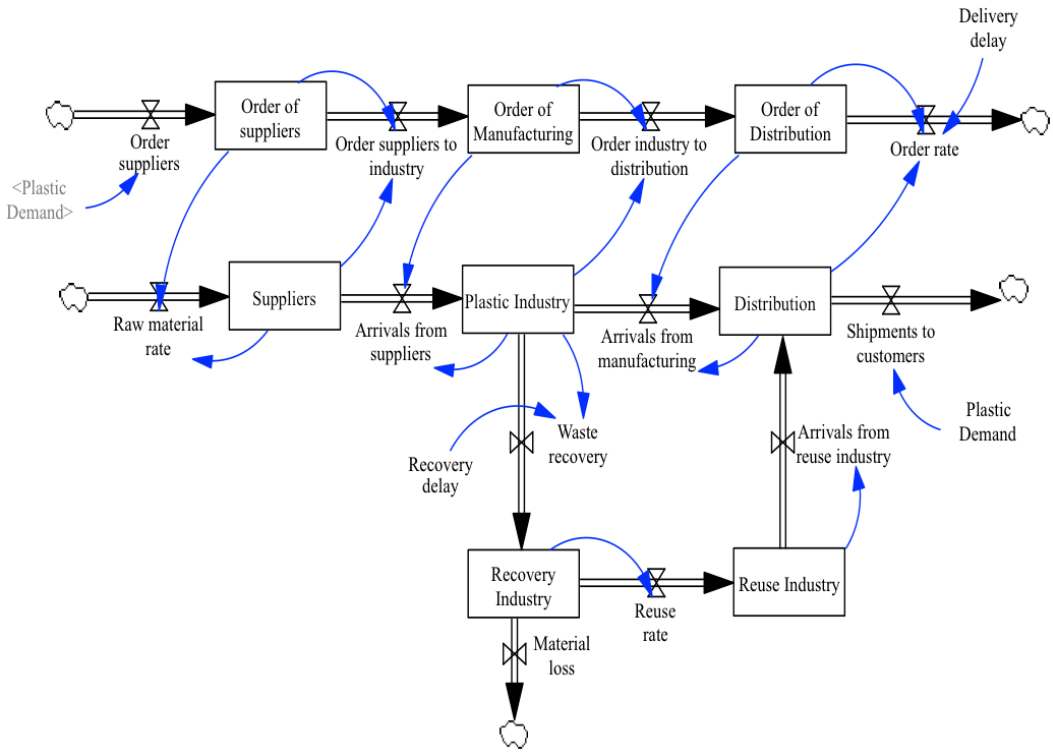
Narasimhan and Kim (2002) studied the effect of supply chain integration on the relationship between diversification and performance in the case of Japanese and Korean firms. The coordination between diversification strategies and performance has a significant effect on firms. Therefore, the new modeling approach is needed to have a better understanding of the dynamic into supply chain mangement. In the past, process management was only established in the early stages of product life-cycle due economies of scale. Currently, dynamic modeling framework involves better decision-making processes that result in a holistic thinking and modeling in supply chain management. The traditional performance assessment approach presented certain limitations due to complex enterprise management and market barriers.

A FOCUS ON THE PLASTIC-SUPPLY CHAIN WITH SYSTEM DYNAMICS MODELING

The complex market network requires of the players integration in the plastic and petrochemical sector for the supply chain management. Figure 4 shows the stock-and-flow diagram through system dynamics methodology. The model is purposely designed for the plastic-supply chain in Colombia. The strategy-structure proposed was based on structures suggested by Orjuela, Herrera and Casilimas (2015), Herrera and Orjuela (2014) and Forrester (1961). This model suggests a better supply chain modeling for the petrochemical industry, as well as greater coordination between customers and suppliers through various information flows. The stock-and-flow connected diagram shows

three players of the plastic-supply chain: suppliers of raw material, manufacturing and distribution. Also, the stock of information is needed (e.g., order backlog). The stock of information consists of orders from the suppliers, industry and distribution. The feedback structure shows the relationship between information and material flows. In this case, the order backlog has an influence on the inventory of suppliers. Therefore, the information flow is linked to most of the physical processes of the plastic-supply chain. Also, it's important to consider the timing of the plastic-supply chain.

Figure 4. Stock-and-flow diagram of a closed-loop supply chain



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As a consequence of the recovery processes, new players of the plastic-supply chain may be linked with another end or start of the closed-loop supply chain. The stocks of recovery and reuseindustries illustrate this point. It was built using descriptions from the players in the plastic-supply chain and recovery closed-loop. In this sense, the drivers in the modeling process can be identified as well as the information and material flows. The major drivers in the plastic-supply chain of the strategic modeling allowed to understand the structure of simulation model. The drivers of the structure of simulation model are presented in Table 1.

Table 1. Drivers of plastic-supply chain in the strategic modeling using the system dynamics methodology

STRUCTURE	VARIABLES	DRIVERS PLASTIC-SUPPLY CHAIN
Information flow	Orders from the suppliers, industries and distributions.	Delivery delay
Material flow	Inventory of suppliers, industries and distributions	Plastic demand
Closed-loop	Recovery and reuse industries	Recovery delay

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The knowledge of the plastic-supply chain as well as the relationships between the information and material flows and the structure of closed-loop, allow the development of a conceptual model for the supply chain management problem. For an instance, the driver of the waste recovery processes affects the capacity of remanufacturing in a closed-loop supply chain.

CONCLUDING REMARKS AND FUTURE RESEARCH

Modeling strategies have gained increasing attention in recent years. Along this line, the study proposes a modeling strategy based on system dynamics methodology. This study concluded that the integration of players in plastic-supply chain needs a holistic thinking approach. Conceptual results show that integrated modeling strategies could be included in supply chain management. Ruiz et al. (2015), argued the importance of external integration of agro-food supply chain. The modeling strategies and holistic approach should also be taken into account in the integration of stakeholders and performance measure design. Others structure of simulation model to food-supply chain is developed by Orjuela et al. (2015).

The integration of product life-cycle analysis in the supply chain design allows long-term sustainability. According to the structure of supply chain, we analyze the recovery strategies of product life-cycle stages. This supply chain structure is important when developing sustainable policies that improve the performance management. Suggestions for future research include: a) Developing a quantitative model based on system dynamics methodology. b) Developing a framework of strategies and connected public and private policy that can be applied in the plastic-supply chain.

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