Computers & Industrial Engineering 72 (2014) 261–273

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Supply chain dynamics and the "*cross-border effect*": The U.S.–Mexican border's case

Miguel Gastón Cedillo-Campos [a,*], Cuauhtémoc Sánchez-Ramírez [b], Sharada Vadali [c], Juan Carlos Villa [c], Mozart B.C. Menezes [d,e]

[a] Mexican Institute of Transportation, Carretera Querétaro-Galindo Km 12, Sanfandila, Mpio. Pedro Escobedo, C.P. 76703, Queretaro, Mexico
[b] Department of Industrial Engineering & Manufacturing Science, Orizaba Institute of Technology, Av. Oriente 9, 852. Col Emiliano Zapata C.P. 94320, Orizaba, Veracruz, Mexico
[c] Texas Transportation Institute, Texas A&M University System, 3135 TAMU, College Station, TX 77843-3135, USA
[d] Haskayne School of Business, University of Calgary, 2500 University Drive NW, Calgary AB T2N 1N4, Canada
[e] ICN Graduate Business School, 13, rue Michel Ney, 54000 Nancy, France

ARTICLE INFO

Article history:
Received 6 August 2013
Received in revised form 24 February 2014
Accepted 16 March 2014
Available online 2 April 2014

Keywords:
Supply chain
Cross-border effect
System dynamics
Freight transportation
Regional competiveness

ABSTRACT

A system dynamics model is proposed for analyzing the uncertainty caused by delays and disruptions at the U.S.–Mexican border, and how their effects propagate through the cross-border supply chains. Since Mexico's geographic proximity and low wages provide logistics advantages to North American Free Trade Agreement (NAFTA), it is becoming a favored manufacturing and logistics location. Nonetheless, crossing the border between U.S. and Mexico remains one of the most important challenges to the NAFTA supply chain competitiveness. Based on literature review and real-life information, the security policies at the U.S.–Mexican border and their cost implications to cross-border supply chains are identified. Information regarding the impact of variability on supply chain dynamics due to "*cross-border effect*" derived of security inspection policies is provided. Results are based on an auto-industry case study that was chosen due to its process standardization; however, results could be applied to other global supply chains. As conclusions, implications for the design of cross-border supply chains are exposed and future research is presented.

1. Introduction

"*Reverse globalization*" is becoming a tendency as firms back off from China to other countries for sourcing and manufacturing requirements (Cedillo-Campos & Sánchez, 2013; Ghemawat & Altman, 2013; SCD, 2011, 2012). Indeed, different technical reports suggest that due to increased energy prices, near-sourcing will rise, which in turn will make global supply chains even more diverse, complex, risky and uncertain (Bueno & Cedillo-Campos, 2014; Hameri & Hintsa, 2009; Ping-Shun & Ming-Tsung, 2013; Serdarasan, 2013; The White House, 2012). Thus, concerning the U.S./Mexican region, "*when you consider the amount of variability involved and the length of time it takes to get from origin to destination, it becomes apparent that companies need to increase their buffer stock. This has changed inventory policies. Consequently, the amount of growth in profits with China is not as great as the amount of profits crossing the U.S.-Mexico border*" (White, 2010). In fact, "*the stability and success of Mexican manufacturing sector is critically important for U.S. interest*" (Haytko, Kent, & Hausman, 2007). From a global point of view, Mexican manufacturing sector provides low-cost goods to United States of America (U.S.) market, a revenue stream for U.S. businesses, a tax base for the U.S. government, economic growth along both sides of the border, and a platform to Latin American markets, which are the "*major market opportunities*" for U.S. products (Bowersox & Calantone, 1998).

In fact, since signing the North American Free Trade Agreement (NAFTA) in 1994, an increasing number of American companies have organized their production systems with material and component supply flows from their subsidiaries located in Mexico or Canada. As a result, supply chains interact more within the NAFTA area. Since there are more interfaces, supply chains are also more dispersed between the three countries. Under the North American Free Trade Agreement (NAFTA), the value of trade between the USA and Mexico by all modes of transportation increased from $97 billion in 1995, to $461 billion in 2011. Even though Mexico has 12 free trade agreements with 44 countries, its economy relies greatly on exports to the U.S., which represent almost a quarter of the country's GDP (U.S. Department of State, 2010). Mexico is the third largest U.S. trade partner; in 2011, it bought more from

* Corresponding author. Tel.: +52 442 216 97 44.
E-mail address: gaston.cedillo@mexico-logistico.org (M.G. Cedillo-Campos).

http://dx.doi.org/10.1016/j.cie.2014.03.015
0360-8352/

the U.S. than any other country with the exception of Canada. In fact, for every dollar of trade between the Mexico and the U.S., Mexico imports almost 43% from the U.S. On the other hand, for instance, China only bought about 20% (RITA – Research, 2013). Nonetheless, crossing the border between these two countries remains one of the most important challenges to the competitiveness of the "*NAFTA supply chains*" (supply chains running operations under the North American Free Trade Agreement area) (Cedillo-Campos, 2012; NACC, 2008; Rodrigue, 2012).

The aim of this paper is to propose a system dynamics (SD) model to analyze the effects of delays as well as disruptions caused by processes at the U.S.–Mexican border and the variability transmitted along the cross-border supply chains. Given the large quantity of variables involved in this analysis, our research was limited to study border crossing times at the most important land port-of-entry in the NAFTA region, the U.S./Mexico border: Laredo, Texas/Nuevo Laredo, Tamaulipas. A research challenge identified by several authors (Knemeyer, Zinn, & Eroglu, 2009; Wu, Blackhurst, & O'Grady, 2007; and Pfohl, Köhler, & Thomas, 2010) who proposed to analyze the local effects of the variability, and at the same time, its propagation effects over other supply chain members, underlining the highly complexity of the task. Actually, the study of large nonlinear systems of this type is a key challenge to even the most skilled control systems researcher.

This paper is organized as follows. Section 2 exposes a general background about the variability on the U.S.–Mexico cross-border flows. In Section 3, we expose a quantitative model based on the SD methodology to measure variability of cross-border process and its impacts on safety stocks. Section 4 presents the results obtained from applying the suggested model to a Tier1 automotive company. Finally, Section 5 provides conclusions and suggestions for future research work.

2. Background

Before the attacks of September 11, 2001, a range of efforts was in place to organize a "*seamless border*" in order to improve regional economic performance on both sides of the U.S.–Mexican border. In that context, the Federal Reserve Bank of Dallas recognized that: "*in short, maquiladoras help the Texas border region move up the economic ladder*" (Vargas, 2001). However, after the 9/11 attacks, U.S.' highest priority became the prevention of another terrorist act. The significant cross-border cooperation started under NAFTA, and reinforced by the signature of the Security and Prosperity Partnership of North America (called NAFTA Plus) has since stalled (Baughman & Francois, 2009).

In fact, in 2009 a total of 9.8 million maritime containers entered the U.S. while the total number of commercial trucks was 9.2 million (BTS, 2011). Despite a similar importance to U.S. trade, considerably analysis has been given to the inspection of maritime containers while less importance has been dedicated to design more efficient inspection process focus on the commercial trucks entering the U.S. from Mexico and Canada. A strategic issue since in the future; increased growth of the regional integration is foreseen, based on logistics flows boosted by the automotive industry as well as by the electronic and aerospace industry. The opportunity to organize one of the largest regional manufacturing zones in the world exists (Black & Rodriguez, 2010; Manners-Bell, 2010); however, if the main reason of the expansion of truck crossings has been the intensification of trade, improving cross-border process is a key issue for NAFTA. In fact, one of the key success factors for the region is to increase cross-border throughput, which is "*the speed and volume with which products move through manufacturing processes, transportation, and customs at the border*" (Lawrence & Leon, 2010). Clearly, Bakir and Pakdaman (2006) argue that: "*Mexican cross-border trucking appears to be in the future of (North American) free trade*."

Ojah, Villa, Stockton, Luskin, and Harrison (2002) identify that the lack of coordination between the U.S. and Mexican authorities is the result of the absence of an overarching forum helping to coordinate planning and border operations. From a cost analysis approach, Villa (2007) exposes as a cause of increasing transaction costs, the large number of non-coordinated public and private stakeholders. As Villa (2007) states, delays are the main problem: "*In 2000, the Mexican Department of Transportation (MDT) estimated the total delay costs along the U.S.–Mexico border at US $77.4 million*". The waiting time can reach several hours (CBP – U.S. Customs, 2012). In 2007, a study developed by specialists from the U.S. and Mexico estimated the cost per year at US$ 246.75 million, only at the Laredo port-of-entry (Colegio de la Frontera Norte and Peschard-Sverdrup & Associates, 2007).[1] It is not easy to distinguish costs due to border security regulations from those caused by insufficient infrastructure or lack of coordination identified by GAO (2000), Ojah et al. (2002), Villa (2007) and Frittelli (2010). Certainly, non-coordinated and non-harmonized security policies on the border have an impact on trade facilitations and consequently, competitiveness performance of cross-border supply chains.

Thus, two basic assumptions appeared in designing an original SD model with uncertain effects caused by delays in a cross-border supply chain: (a) the lack of standardized security processes and safety inspections on the border, and (b) the differences in transport infrastructures at both countries. These elements create variability in crossing times (Haralambides & Londono-Kent, 2004). The disturbance and occasionally, disruptive influence of variability seem to be a key element degrading the performance of the cross-border system.

Essentially, the variability of the processes involved in border crossing is transmitted all along the NAFTA supply chains which not only generates direct costs associated with running vehicles but also imposes costs to shippers via inventory and safety stocks that companies have to maintain for responding to the demands of the market (Ojah et al., 2002; Rajbhandari, Saman, Vadali, Kang, & Samant, 2012). Consequently, variability in the process of border crossing is added to the variability of the market, increasing the consequences of a created (by inefficiencies) propagation of variability across U.S.–Mexican supply chains. In addition, while proximity is a plus for the Mexican manufacturing system compared to other global suppliers, the time to cross the US/Mexican border is often a concern for both the northbound and southbound direction shipments (Haytko et al., 2007). Actually, a portion of this problem is caused by efforts of both governments to stop the flow of drugs, illegal immigrants, weapons, and money. However, even though a minor fraction of the total flow of trucks crossing the border every day could carry illicit goods, it is imperative to design and organize an efficient inspection process to recognize and eliminate threats to the U.S./Mexican national security (Xue & Villalobos, 2012). In this sense, Koh (2007) argues that global supply chains running operations under a just in time environments, widely practiced today, highly depend on the efficiency of the border crossing. He states that the introduction of strict controls at international borders, product of greater attention to terrorism, is increasing global trade cost and consequently, decreasing global economic growth. Nevertheless, his research is descriptive and does not propose any methodology to help assess the quantitative impact of the border as a disruptive source.

[1] The Colegio de la Frontera Norte (Northern Border College) is a research center that belongs to the National Council of Science and Technology (CONACYT) in Mexico.