

# The Impact of Payment delays on The Financial resilience of a Multi-echelon Supply Chain: a System Dynamics simulation Approach

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## Abstract

Using system dynamics modeling and simulation on a moroccan retail industry, we investigate whether and how delay in payment enhance supply chain resilience. Potential risks for the retailer's resilience performance include the possibility of a mismatch between supply and demand, as well as serving the store inefficiently and causing on-shelf stock-outs due to the lack of cash-flow. Thus, resilience is determined by investigating the dynamic behaviour of stocks, shipment responses, cash in hand, and invoices payments. We show that retailer's that face liquidity shocks are more likely to default on their market response, especially when the shocks are unexpected, supply chain partners with little liquidity, are likely to be credit constrained or are close to their debt capacity. Credit constrained firms would thus pass on their liquidity shocks on to their suppliers down the trade credit chain, we show that firms provide liquidity insurance to each other and that this mechanism is able to alleviate credit constraints. The method allows insights into the system structures that would not be evident using simulation alone, including a better understanding of the influence of control parameters on dynamic behaviours, and the impact of payment delays on supply chain resilience.

## 1. Introduction

Over the course of history, supply chains have emerged to meet the diverse needs of human societies, to exploit natural resources, and to enable humans to engage profitably in commerce and trade. (Casson, M. (2013). The very extensive supply chain literature addresses supply chain practices and performance ( Swink et al., 2007; Flynn et al., 2010), supply chain strategies and their dynamics over time ( Ketchen & Giunipero, 2004; Skjøtt-Larsen et al., 2007), and to some degree addresses changing supply chain configurations ( Halldorsson et al., 2007; Ülkü & Schmidt, 2011), as manager strive to improve factory performance, the trouble is that often the meaning is lost (Zeng et al ; 2017), while interest in SCM is immense, it is clear that much of the knowledge about SCM resides in narrow functional silos such as purchasing, logistics, IT and marketing(burgess et al ,2006), The different interactions constitutes a complex set of relationships among buyers and suppliers, between a buyer and a supplier as well as between competing suppliers (Nair et al, 2008), so the supply chain management involves adapting to changes in a complicated global network of organizations (pathak et al, 2007), and thus we will not examine it as a set of sequential, vertically organized transactions representing successive stages of value creation (Mabert & Venkataramanan, 1998) but as a whole system. Managers must possess a mental model of a supply chain management that more accurately reflects its true underlying complexity and dynamism. (Choi et al, 2006), so due

to our natural lack of understanding of organizational, functional and evolutionary aspects in supply chains. A key realization to tackle this problem is that supply-chain networks should be treated not just as a 'system' but as a 'Complex Adaptive System (Surana, 2005), and naturally it should be managed as such (Choi, 2006), however the dynamic and complex evolution of markets has encouraged many firms to implement various supply chain initiatives to try to boost efficiency (Saenz, 2017). As a result, aspects such as operational complexity and dispersion are making the supply chain more vulnerable to risks that negatively affect both short- and long-term operational and financial performance (Saenz, 2017; Craighead et al, 2007; Rao & Goldsby, 2009; Sheffi, 2005; Thun & Hoening, 2011). In recent years, there have been a number of high-profile events and persistent problems that have severely disrupted the ability of firms to produce and distribute their products, including devastating earthquakes, political turmoil, fuel crises, diseases and terrorism (Chen et al 2013; Sodhi 2016; Mandal 2014; Singhal et al 2011). Indeed, a firm that responds to a disruption better than its competitors could improve its market position (Tukamuhabwa, 2015), so The potential impact of disruptions on a firm and its supply chain make a clear case for the importance of building resilience (Carvalho, 2012), there are even extreme cases where supply chains have completely collapsed and never recovered from a disruption (Xu et al 2014). One of the substantiated issues in supply chain dynamics is resilience, which refers to development of the ability to remain robust and change (adapt) system behavior in dynamic environments in the case of severe disruptions with the achievement of acceptable performance (Craighead et al. 2007; Ivanov et al. 2016; Benyoucef et al. 2013; Ho et al. 2015; Gunasekaran et al. 2015; Tukamuhabwa et al. 2015; Khalili et al. 2017; Ivanov, 2017)

## **2. Mathematical Model**

This research evaluates the impact on of delay in payment in supply chain resilience among grocerie retailers and their distributors. The research attempts to clarify the benefits of payment delays trough modelling decision making rules within a case study SC. A dynamic model is developed based on actual data collected from case participants. The study was conducted in Morocco. Supply chain managers, store managers, dairy managers, category managers, and executive marketing managers were consulted and interviewed to help build up the structure, parameters and decision rules for a causal loop diagraph. Order data from 12 retailers in the 10 different citys around morocco and their distributor are collected and summarized as a basis for modelling alternative decision rules using system dynamics.

### **2.1. Model notation and assumption**

Current research define the parameters that will be used to build mathematical models in this research as mentioned below:

- $K$ = set of all invoices
- $L_k$ = invoice amount for invoice  $k \forall k \in K$
- $U_k$ = discount rate on the invoice  $k$ 's amount  $\forall k \in K$
- $b_k$  the time on or before which the invoice  $k$  needs to paid to get the discount  $u_k \forall k \in K$
- $d_k$  due date for the invoice  $k \forall k \in K$
- $V_k$  penalty or interest rate per period if the invoice  $k$  is not paid on or before
- due date  $d_k \forall k \in K$
- $S_k$  time at which invoice was generated by the upstream partner  $\forall k \in K, s_k \leq b_k \leq d_k$
- $Q_t$  total amount received from all downstream partners at time  $t$

In order to simplify the formation of model, several assumptions are defined which will be used for this model development, such as:

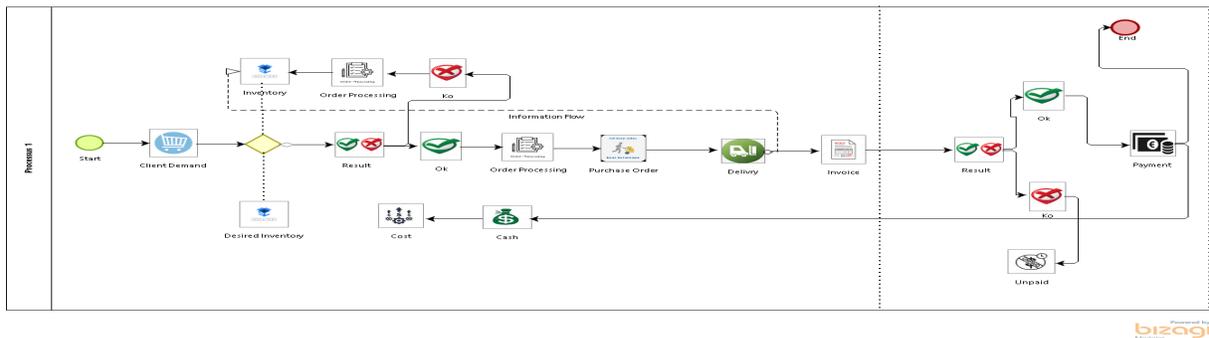
- One supplier, one manufacture, one wholesaler, and one retailer and multiple final clients.
- Final Demand is deterministic and constant over time.
- Only consider one product.
- The supply chain's parteners objective is to minimize cash out flow to pay all invoices.

## 2.2.Data Collection Method

Semi-structured interviews have been selected for collecting data from 12 retailers in 10 different cities in Morocco. The interviews allowed the respondent to tell stories, give examples and clarify the problem definition. An initial system dynamics model was built to characterize the problem through discussion with the participants. This information was supplemented by archival research. Interview questions were designed to focus on the SC participants' levels of understanding about the real impact of delay in payments with their supply chain partners, through asking them to share any information relating to the aspects of their involvement with other suppliers and distributors. In their SC (such as order quantities, sales forecasting, customer demand, inventory management, stock level and promotional strategies, etc.). Moreover, they were asked about how they assess their business relationship with distributors and how they measure the effect of payments delays in terms of risks and benefits from their perspective on their level of market share. Specifically, they were asked about the relationships between sharing order information with distributors and competitive advantage, and the collaboration conditions and barriers from the retailer's point of view. From the previous questions during interviews, the research found that most of the 12 retailers have the same conceptual understanding of collaboration as a means to contacting their supplier and distributors through just sharing current daily orders. It was noted that they didn't share any other information about previous orders, future orders, sales forecasting, stock, and inventory management, nor did these small retailers retain historical data for all their ordering. They merely depended on making decisions based on the historical data provided by their distributors.

## 2.3.Model Boundary and Description

Our model was developed on the basis of supply chain models reported in the literature, but was modified and refined to fit the case study presented in this article, thanks to different interviews and dialogues with supply chain partners. In addition, relevant variables, parameters, and feedback loops related to the effect of late payments were added to the model from the interview results to provide a fully validated case study simulation model.



**Figure 1 process mapping from payment to delivery**

Using Bizagi process modeling software, the figure above shows the process flow from order to payment in a single echelon supply chain.

## 3. Model formulation

### 3.1.Invoice modeling

Let us assume,  $qt$  be the total money received by the wholesaler from all downstream partners at time  $t$ . We denote  $L_k$  to be the invoice amount for the  $k$ th invoice from an upstream partner received at time  $s_k$  an invoice is generated by a supplier after shipping the products to the wholesaler. The objective of the wholesaler is to schedule the

payments of these invoices to the upstream partners within the constraints of the receipt of the money from the retailers. If invoice  $k$  is paid before a certain date, denoted as  $b_k$ , the terms of payment of the invoice guarantees a discount  $u_k$ . (Gupta et Dutta,2011) This discount by upstream partners is given to encourage early payment of the invoice by the wholesaler. However, a penalty or interest  $v_k$  has to be paid if the payment for invoice  $k$  is not made within a due date  $d_k$ . It may be noted that  $s_k \leq b_k \leq d_k$ . Any money that is accumulated with the wholesaler can be invested to earn an interest. The wholesaler's objective is to minimize cash out flow to pay all invoices.

$$A_k(t) = \begin{cases} l_k * (1 - u_k), & \text{if } s_k < b_k \\ L_k, & \text{if } b_k < t < d_k \\ L_k * (1 + v_k)^{t-d_k} & \text{if } t > d_k \end{cases}$$

We also need to specify cash balance equations to ensure that the total cash in hand is more than or equal to the total payments made against one or more invoices in each time interval, on each month. The cash in hand in each time interval is equal to the total cash inflow received so far, plus the interest earned on the cash-in-hand minus the total payment of invoices made so far and the total payment of the operating costs including workforce, rent and day to day expenses. Additionally, we assume that all cash transactions occur at the end of each time interval, we will have the following constraints to balance the cash inflow and outflow on each month

$$BC = \delta + q_1 - \sum_{\forall k \in K} X_{k1} A_k + \psi(1)$$

Where  $\delta$  equal cash in hand at the beginning and  $q$  is the amount received from all down Stream partners. Our invoice equation was modified as we consider operating cost, like workforce and facilities, included in the depenses of the supply chain partner.

- Initial Invoice =supplier's sells price\*shipment, Units: Mad

The same rules and patterns will be applied to suppliers, semi-wholesalers and retailers.

### 3.2. Supply chain disruption modeling

Most of the studies in the field of supply chain risk management consider disruption as a probability of occurrence of an event with negative consequences (Ali et al,2017 ; Manuj, Esper, and Stank 2014; Manuj and Mentzer 2008b; Matook, Lasch, and Tamaschke 2009; Wagner and Bode 2008). Christopher and Peck (2004) advise that risk can emerge from three main levels; internal to the firm, internal to the supply chain, external to the supply chain. A comprehensive understanding of risks thus needs to consider all three sources, simultaneously (Christopher and Peck 2004). Sidisin (2003) found that risk can be perceived as a multidimensional concept. Different companies will define risk based on their individual objectives and desired outputs. Moreover, within a company, risk concepts among different managers may be related to different outcome variables such as commercial (e.g. inventory levels), safety (e.g. risk to life) and political issues (e.g. political ramification) (Juttner et al. 2003). Our study simulate a financial crisis where unpaid rate increase by 10% per month then decrease after one year by 10% to attain the initial rate and is summarised as the follow equation.

- $MAX(m, m*(1+SMOOTH(0.1,12)+SMOOTH(-0.2,24)))$ , where  $m$  is the initial unpaid rate of the total invoices

### 3.3. Demand Modeling

We modeled the demand based on the work of Elkady et al (2014) where system dynamics was applied to Assess Grocery Retail Supply Chain Collaboration, and the work of Liu et al (2016) where system dynamics was used to analyze agri-food supply chain operation modes.

- Average order rate=SMOOTH (Wholesalers order, time period for averaging orders), Units: units/Week:  
The firm forecast shipments by averaging past orders over time period as a way of smoothing out any noise or lumpiness in demand.
- Time period for averaging orders=constant, Units: month
- Inventory correction time=constant,Units: Week
- Time period for Averaging orders= constant, Units: month
- Order= Desired Inventory- Inventory, Units: units/Week

### 3.4.Production modeling

As the aim of the study was not to asses production, we considered desired production as sum of the average order and the dynamic inventory correction, with a production capacity constraint.

- Desired production=average order rate + Inventory Correction Units: units/Week
- Production = Production rate, Units: units/month
- Production Rate: IF THEN ELSE (Desired production  $\geq$  Production capacity, Production capacity, Desired production) , Units: units/Week, the desired capacity can't exceed the production capacity
- Production Capacity= constant, Units: units/month

### 3.5.Costs modeling

- Cost per product = auxiliary that need to be defined based on inventory Correction= (Desired Inventory- Inventory)/Inventory correction time, Units: units/Week
- Shippement cost = defined based on shippement quantity IF THEN ELSE (shipment  $\geq$  M, order\*M, order\*N) , Units: units/Week, where the unit cost depend on the order size.
- Supplier Sells Price= IF THEN ELSE (Orders>n,N,M), Units : Mad, often the price change in regards of the order, if order exceed n the price is N, if not the price is M

### 3.6.Inventory modeling

- Inventory= INTEG (Production-Shipment, initial), Units: units
- Inventory correction time= constant, Units: Week, auxiliary that need to be defined based on the case study.
- Wholesaler's Inventory = INTEG (supplier's shipment –Wholesalers shipment) Units: units

### 3.7.Supply chain surplus

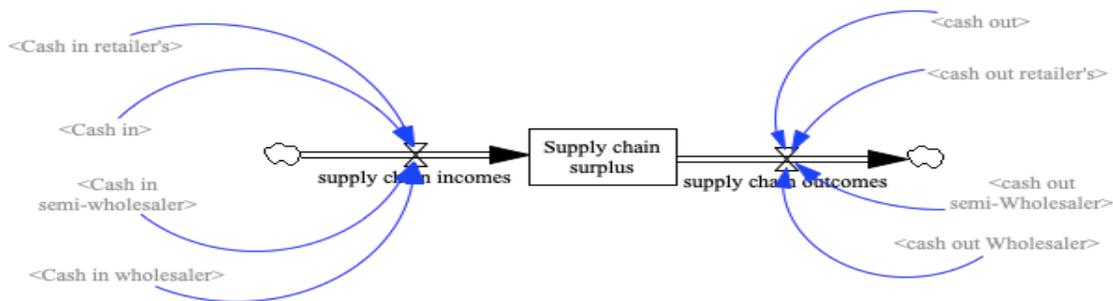


Figure 2 causal loop diagram for supply chain surplus

- Supply chain surplus = Cash in – cash out

#### 4. Simulation

In practice, vendors often provide buyers with forward financing, in the first simulation, we consider that there is no delay in payment, so the buyer can not ship more than he can afford to, and thus we consider that the cash in hand is superior always than or equal to order quantity \* sells prices, as he ordered quantities can not exceed the cash available for it

- IF THEN ELSE (Cash in hand  $\geq$  supplier sells price \* order, Wholesalers order, Cash in hand wholesaler/supplier sells price)
- Demand = MAX(1e+06, 1e+06\*(1+Step(-0.2,12)+Step(0.3,24)))

As described before the aim of the study is to assess the impact of permissible delay in payment on the financial resilience of a multi-echelon supply chain, we consider a multi-echelon supply with and without permissible payment delays, before and after the occurrence of a disruption.

##### 4.1. Supply chain surplus before disruption:

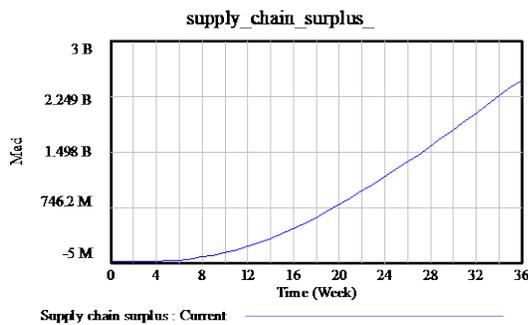


Figure 3 SCSP without PD

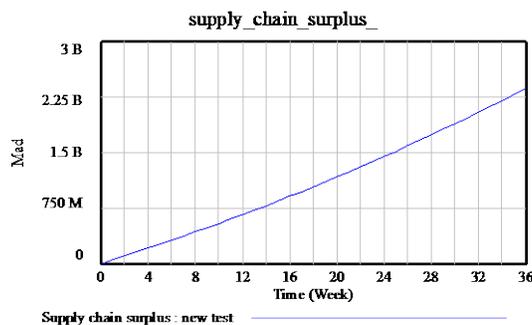


Figure 4 SCSP with PD

In a stable economic situation, supply chain surplus increase without Payment delays and is always positive

##### 4.2. Supply chain surplus after disruption:

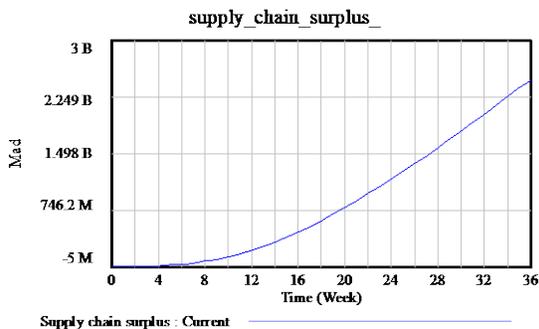


Figure 5 SCSP with PD

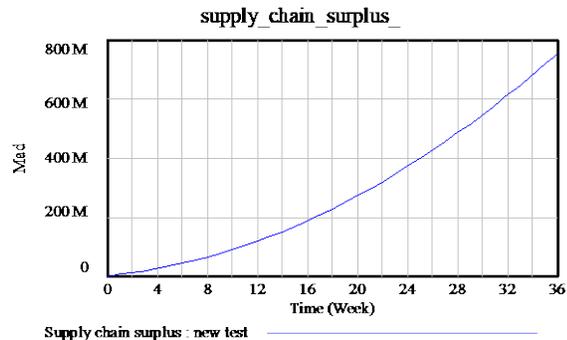


Figure 6 SCSP without PD

The simulation show that in a situation of a financil crisis with high, unpaid rate, the simulation show that a supply chain with permissibl payment delays, abosrb the disruption better and the supply chain surplus, in contrast with a stable economy, change drastically.

### 4.3.Sensitivity analysis

<b>Ratio inventory</b>	<b>1%</b>	<b>3%</b>	<b>6%</b>	<b>9%</b>	<b>12%</b>
<b>Units</b>	<b>Margin</b>				
<b>10.000</b>	9,29%	7,19%	4,97%	0,88%	<b>-2,28%</b>
<b>100.000</b>	10,84%	8,74%	6,52%	2,43%	<b>-0,72%</b>
<b>1.000.000</b>	11,00%	8,90%	6,67%	2,59%	<b>-0,57%</b>
<b>10.000.000</b>	11,02%	8,91%	6,69%	2,60%	<b>-0,55%</b>
<b>100.000.000</b>	11,02%	8,91%	6,69%	2,60%	<b>-0,55%</b>

As reported in the litterature, payment delays permit to alliviate inventory, by selling more, our analysis show that the inventory have a direct impact the profit margin per product.

The margin decrease as it's reach a negative point when the non solded inventory is equale to 12%

<b>Ratio Inpaid</b>	<b>1%</b>	<b>3%</b>	<b>6%</b>	<b>9%</b>	<b>12%</b>
<b>Nb Unite</b>	<b>Margin</b>				
<b>10.000</b>	9,47%	7,71%	4,97%	2,43%	<b>-0,21%</b>
<b>100.000</b>	11,02%	9,26%	6,52%	3,98%	1,34%
<b>1.000.000</b>	11,17%	9,41%	6,67%	4,14%	1,50%
<b>10.000.000</b>	11,19%	9,43%	6,69%	4,15%	1,52%
<b>100.000.000</b>	11,19%	9,43%	6,69%	4,16%	1,52%

The sensivity analysis proved a light impact of the unpaid rate on the margin, as the volume of units is important.

## 5. Discusion

By using system dynamics mdeling and simulation on on a moroccan retail industry, we showed, based on a real life case study, how payment delays impact supply chain behavior. The study proved that in a case of financial crisis, where demand dropped drastically, payment delays increase significantly as the supply chain surplus reached 3 billions, as it's alleviate inventory and reduce costs across supply chain.

## 6. Conclusion

This paper presents findings of a simulation that managers can use to unlock the power of delay in payments along the cross cutting themes identified in the study. The findings show that the payment delays is a nowadays necessary tool to do business and supply chains should embrace it in order to build superior capabilities which can become a decisive competitive advantage. Organizations need to leverage the information across supply chain to share the real time information, better understand customers, optimize supply chains and human resources, improve financial metrics and develop the critical insights for decision making. It is important to have an

acceptable conceptual framework for capturing the business value in a systematic manner in this research stream. Therefore, financial resilience is impacted directly by payment delays. Therefore, future research can include opportunistic behavior and the impact of the redundancy of transactions.

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