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Network Modelling and Simulation for Scheduling Problems Under Restrictions in Invested Capital

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Abstract:–This study aims at providing solutions on scheduling problems under restrictions in capacity, invested capital value and number of stocking points. We will discuss some dynamic processes that managers must dominate to compete in today's marketplace, specifically network design and inventory management. The approach we present is based on an optimization model emphasizing the effect of market demand uncertainty and the relevant dimensions of network design. We present solutions that will enhance supply chain and the impact it has on the company's financial success, considering logistic and inventory costs. Overall, this study will explore the role of integrated communication on invested capital management, and the impact of the supply chain network design and inventory location. The challenge is also to reveal how supply chain leaders can increase the value to their companies under global solutions and sources of business profitability in a dynamic environment. Finally, we discuss the sensitivity of the results to changes in key parameters, including the unbalanced network capacities, number of stocking points, value restrictions and non-optimal values.

Keywords:–scheduling, network modelling, market uncertainty, supply chain management

I. INTRODUCTION

In the current economic and industrial conditions, with demand ever fluctuating, stressed by shocks, we focus on the scheduling mechanism, based on network balanced capacity and restrictions. We target the decision on how flexible firms should endow their operations balancing the invested capital on stocks.

The context for the problem identification is related with the need to understand the inventory distribution in a supply chain, as it has become a critical issue in business cycle analysis under conditions of market uncertainty. The costs of carrying inventory have always been relevant, but in today's scenarios, there is a major concern related to capital costs. Therefore, inventory and network design optimizations are significant topics in supply chain circles today, considering the dynamic state of markets all over the world.

To optimize invested capital on stocks, we need to manage the uncertainties, constraints, and complexities across a multi-stage supply chain on an operational and continuous basis. As so, many companies adopt inventory control systems, which enable them to handle many variables and continuously update in order to optimize the multi-stage supply chain network.

Scheduling activities must consider the imprecise nature of forecasts of future demands and the uncertain lead time of the upstream stages network. These are normal situations, and the answers managers' get from a deterministic analysis very often are not satisfactory when high market demand uncertainty levels are present. The retailers want enough supply to satisfy customer demands, but ordering too much increases holding costs and the risk of losses through obsolescence. In addition, a small order increases the risk of lost sales and unsatisfied customers.

This study is aimed to investigate the impact of capacity restrictions between different nodes of a supply chain and number of stocking points, considering the impact of demand uncertainty. We intend also to evaluate the impact of non-optimal and unbalanced stock values, considering restrictions in the invested capital value along the different decisions points in the supply chain.

In particular, the model intends to answer four practical questions: (1) What is the impact of capacity restrictions on the inventory values along the network? (2) How can the design of the network, specifically the number of stocking points, affect the global inventory value? (3) What is the impact of financial value restrictions on scheduling problems? (4) How can we quantify the impact of unbalanced decisions on inventory values, for each decision point along the network?

This paper is structured as follows. In the next two sections, the background theory is supported and the reasoning for the used technique to solve the problem is presented. Section 4 illustrates the valuation framework. Section 5 discusses the results and the paper concludes in section 6.

II. LITERATURE REVIEW

A supply chain is a network of facilities and distribution options that functions to procure materials, transform these materials into intermediate and finished products, and distribute those to customers (Cutting-Decelle et al., 2007). Logistic operations are designed to maximize outputs and speed in materials flow at lower costs. Supply chain configuration is concerned with determining supply, production and stock levels in raw materials, work in process at different levels and end products, also with the information exchange through a set of factories and distribution network to meet fluctuating demand requirements. Different network configurations include: (1) different stocking levels; (2) optimal stock location; (3) production policy (make-to-stock or make-to-order); and (4) production capacity (amount and flexibility). It has been widely accepted that supply chain configuration, such as decisions on where the inventory should be placed, can affect the company performance (e.g. Garavelli, 2003), which justifies the relevance of the theme in literature. In general, decision variables for supply chain configuration such as center locations, transportation (Zeng and Rossetti, 2003), inventory, demand, and product variety have been identified in the literature (Ma and Davidrajuh, 2005). Typical objectives of supply chain configuration, besides cost minimization, are safe inventory levels, maximum customer service level (Guillén et al., 2005), and improved relations between parties (Leger et al., 2006).

The global network must be designed and operated to recognise the potential optimal stocking location decisions (nodes) (Tsiakis, Shah and Pantelides, 2001; Graves and Willems, 2001; Daley, 2008), also as ultimate purpose of a product sold in the foreign market (Hsu and Zhu, 2011). Demand volatility impact also differs depending on the center location within the network; the more upstream a center of the supply network is (far from the consumer), the greater the risk of distortion in demand information. Such distortion can be reduced if downstream supply chain partners share reliable information on the status of their inventory (Lee, Padmanabhan and Whang, 1997; Samaddar, Nargundkar and Daley, 2006). Recent studies have been concentrating on relevant aspects that can be subdivided into strategic alignment, coordination and number of nodes, geographical presence, and design of the global distribution network (e.g. Hume, 2003; Lovell, Saw and Stimson, 2005; Liu et al, 2008; Srai and Gregory, 2008; Creazza, Dallari and Melacini, 2010; Moser et al., 2011). According to Irving et al. (2005), Banker (2009) and Oster (2009), companies can benefit from adopting a financial and logistic perspective, like the location of functions, assets and risks evaluation, on supply chain design.

The first approaches to profit maximization models, have considered a deterministic demand approach and were proposed by Nagurney, Dong, and Zhang (2002). Later on, Dong et al. (2005) presented a model for the study of supply chain networks within multi criteria decisions, aiming profit maximization, transportation time minimization and service level improvement. Most of existing literature, by addressing global network structures, business processes and management components (Lambert, Cooper and Pagh, 1997), focus on configuring supply chains using cost and tied-up capital minimization (Arntzen et al., 1995), customer service maximization (Zhang and Saboonchi, 2008) through lead times reduction and more responsive and agile order-to-delivery processes, optimal inventory replenishment strategies and routing decisions under optimisation techniques (e.g. Daskin and Coullard, 2002). Our approach differs from the large variety of decision support models and corresponding solutions for strategic design of supply chains, as there does not appears to exist a model using real options methodology, enhancing flexibility in the decision process, addressing simultaneously network design, capacity restrictions, inventory and lead time and service level, in distribution network configurations under customer demand volatility. Most of the past literature reinforced the need of integrated decisions supported on a multi-echelon approach and on information coordination aiming the goals congruence (e.g. Banerjee et al., 2007; Chan and Chan, 2009; Mangal and Chandna, 2009; Liu et al., 2011). Some authors presented solutions to minimize distortions related with incentives and lack of information. Chen (1999) considered information delays in multi-echelon framework and proposed incentive schemes between echelon managers aligned with the firm, however, requiring the presence of a central planner. Forslund and Jonsson (2007), following Petersen et al. (2005), posted a special attention on the role on accurate, reliable, timely, accessible and valid information on the supply chain planning; whenever partners without reliable information use higher levels of safety stock. Tan (2008) used the imperfect advance demand information in forecasting. Chan and Chan (2009), proposed an information sharing approach in multi-echelon supply chains to convey exact inventory information to upstream stages, using a simulation approach to test the effectiveness of such methodology. Recently, Li (2010) posted a specific attention on the importance of demand information track between different stages. Overall, this application contributes to the techniques used in scheduling problems under uncertainty, considering restrictions in the network balancing for different decision points.

We use table 1 to make a brief of the main differences between the present study and other common approaches for inventory management.

Table 1: Scheduling options vs. other approaches

Key areas	Sequential approach	Distribution requirements planning	Scheduling options
Optimisation objective	Meet customer´s service targets at minimum inventory levels	No optimisation. Replenishment needs depend on upstream requirements	Meet end-customer service level at optimal stock level for all the network
Demand forecasting	Independent forecasts in each echelon	Pass-up demand orders	Stochastic model to represent the demand
Lead times	Suppliers lead times are used, considering variability	Suppliers lead times are used, ignoring variability	Uses all lead times and variations
Network visibility	Immediate downstream customer and upstream supplier	Some downstream visibility but no upstream visibility	Full visibility for all echelons
Cost function implications between echelons	Not possible	Not possible	Can be modelled

III. REASONING TO CHOOSE REAL OPTIONS TO SOLVE THE PROBLEM

First we concentrate on the techniques to be used. Companies facing market uncertainties have three basic alternative solutions to solve inventory problems. First, they can simply guess for uncertain quantities and proceed with one of the deterministic models under different scenarios. Second, they can develop mathematical models to deal with uncertainty. The disadvantage of this approach is that analytical models with closed solutions can be very complex and difficult for many managers to understand. The third option to capture the market uncertainty is to develop a simulation model. The advantage of the simulation model (e.g. Monte Carlo) is that it is relatively easy to develop regardless of the complexity of the problem under analysis. In this work both situations will be theoretically explored, considering stochastic market demands. On the other hand we have the conceptual problem. It is not appropriate to forecast demand as a normal distribution, where demand positive or negative shocks are possible and can be generated in highly uncertain markets. In addition, a traditional approach with demand distribution does not consider the information arrival that significantly affects the future demand. In highly uncertain markets, the decision-makers are not sure whether the current demand will go up or down. This situation is closely related to the financial option-pricing problem. Therefore, we adopt the framework of option pricing to model an inventory problem in an uncertain environment.
The following table refers to the analogy between financial option and scheduling decision.

Table 2: Analogy between financial options and scheduling options

Financial options	Scheduling options
Stock price	Demand
Exercise price	Initial inventory level
Time to maturity	Planning period
Stock volatility	Demand volatility

IV. MODEL

In this investigation, we follow Tan (2002) assuming restrictions in the available manufacturing and storage capacity and out-put rates equilibrium within the planning period. We ignore the use of an outsourcing (subcontracting) alternative. A model is presented not only based on abstractions of the real world, but whose illustration case can provide guidance and insight to the inventory management within companies in the actual uncertainty environments.

The model takes into account three important characteristics of real problems, such as production/storage capacity limits, multi-product production and uncertainty in demand flows. In this work, we try to overcome these actual problems by presenting a new model which contemplates both inventory value and distribution in the context of a multi-stage network, and which allows for a multi-product environment with limited capacities and uncertainty in the demand flow. A real options formulation model is proposed and adapted to allow an easier application to real life problems, without a loss in generality. We solve the model for an industrial company case study and present the results.

Our results are valid for the specific supply chain and the operating environment we used in the model. Nevertheless, we must emphasize the generality of the model to incorporate different supply chain designs and stages interactions, considering limitations in supply chain partners cooperation and information flow.

The network stages are sequentially undertaken and the time framework depends on the operations sequence and lead time. Downstream stages can be only undertaken after previous stages. The optimal stock is split across an integrated supply chain, which allows risk minimization without committing to a major invested capital. Each stage has its own operations, time processing activities, lead time, resources, capacity constraints and output rate.

The parameters and the objective function will follow.

.Sets to support a general application for different network designs:

- $\hat{F} = \{1,\ldots,N_p\}$ potential factories, within supply chain A
- $\hat{W} = \{1,\ldots,M_q\}$ potential warehouses, within supply chain A ,
- $Z = \{1,\ldots,X_l\}$ items' classification

.Parameters

- ($\gamma^p_{(f)-(f+1)}$) Relation between out-put units factory f and $f+1$, $f \in \hat{F}$ (equivalent finished units).
- (g^p_f) Maximum capacity of factories, $f \in \hat{F}$
- (g^q_w) Maximum capacity of warehouses (or distribution centres), $w \in \hat{W}$
- (c^p_f) Unit cost of factory, $f \in \hat{F}$
- (c^q_w) Unit cost of warehouse (or distribution centre), $w \in \hat{W}$
- (L^p_f) Lead-time of operations in factory, $f \in \hat{F}$. Lead time is the amount of time from the point at which one determines the need to order to the point at which the inventory is on hand and available for use.
- (L^q_w) Lead-time of activities in warehouse (or distribution centres), $w \in \hat{W}$
- (S^p_f) Service level assumed by factory, $f \in \hat{F}$.
- (S^q_w) Service level assumed by warehouse (or distribution centres), $w \in \hat{W}$. Represents the % of the quantity fulfilled on the required date
- (k^q_f) Holding cost for inventory in factory (intermediate stock), $f \in \hat{F}$. This is the cost of holding an item in inventory for some given unit of time.
- (k^q_w) Holding cost for inventory in warehouse (or distribution centre), $w \in \hat{W}$. This is the cost of holding an item in inventory for some given unit of time. It usually includes the lost investment income caused by having the asset tied up in inventory. This is not a real cash flow, but it is an important component of the cost of inventory.
- ($r = 1 + r_\eta$) The discount factor, where r_η is the risk free interest rate.
- (j) The weighted average cost of capital, reported and adjusted to the planning period.
- ($1 - S^p_f$) Stock-out rate in factory $f \in \hat{F}$. When a customer seeks the product and finds the inventory empty, the demand can either go unfulfilled or be satisfied later when the product becomes available. The former case is called a lost sale, and the latter is called a backorder. Anyhow, both situations are disturbing and count for the stock-out rate.
- (h) The stock aging factor. This parameter quantifies the items obsolescence, due to storage time.
- (τ^f_{f-1}) Cycle time. The time between operations in consecutive network stages. Is the cycle time between factory, $f \in \hat{F}$.
- (I^f_0) The existing intermediate inventory level in factory, $f \in \hat{F}$ in the beginning of the planning period.

- (I_0^w) The existing final products inventory level in warehouse (or distribution centres) at the beginning of the planning period, $w \in \hat{W}$.
- We hereafter employ the additional notation p_v for the unit sales price and K_f^p and K_w^p for the value calculated as a function of the stock-out rate (normal distribution), for each factory $f \in \hat{F}$ and warehouse $w \in \hat{W}$, respectively.

.Decision variables

- Maximum stock value allowed for each factory (Ω_f)
- Maximum stock value allowed for each warehouse (or distribution centre) (Ω_w)

The model considers:
Max (demand, costs, time, service, obsolescence, initial stock)
Using the above definitions, the model (Ω_f and Ω_w) is formulated as follows, by each item category:

$$\max\left[0; D_z.\sum_{f=1}^{N}\Phi_{zf}^{p} + D_z.\sum_{w=1}^{M}\Phi_{zw}^{q} - \sum_{f=1}^{N} I_{z0}^{f} - \sum_{w=1}^{M} I_{z0}^{w}\right],\ \forall\ z \in Z \tag{B.1}$$

With,

$$\begin{aligned}\Phi_{zf}^{p} &= c_{zf}^{p}.L_{zf}^{p}.K_{zf}^{p} - \left(p_{zv} - \sum_{i=f}^{N} c_{zi}^{p}\right) + S_{zf}^{p}.\left(p_{zv} - \sum_{i=f}^{N} c_{zi}^{p}\right) - \\ &- L_{zf}^{p}.K_{zf}^{p}.c_{zf}^{p}.j - L_{zf}^{p}.K_{zf}^{p}.c_{zf}^{p}.h_z - L_{zf}^{p}.K_{zf}^{p}.k_f^p\end{aligned} \tag{B.2}$$

$$\begin{aligned}\Phi_{zw}^{q} &= c_{zw}^{q}.L_{zw}^{q}.K_{zw}^{q} - \left(p_{zv} - \sum_{i=w}^{M} c_{zi}^{q}\right) + S_{zw}^{q}.\left(p_{zv} - \sum_{i=w}^{M} c_{zi}^{q}\right) - \\ &- L_{zw}^{q}.K_{zzw}^{q}.c_{zw}^{q}.j - L_{zw}^{q}.K_{zw}^{q}.c_{zw}^{q}.h_z - L_{zw}^{q}.K_{zw}^{q}.k_w^q\end{aligned} \tag{B.3}$$

s.t.

- $g_f^p \geq g_{f+1}^p.\gamma_{(f)-(f+1)}^p \geq \ldots \geq D,\ \forall\ z \in Z$
- $g_w^q \geq D,\ \forall\ Z \in Z$
- $\sum_{f=1}^{N}\sum_{z=1}^{X} \Omega_{zf}^{p} \leq \sum_{f=1}^{N} R_f$, R_f is the capital restriction for factory $f \in \hat{F}$
- $\sum_{w=1}^{M}\sum_{z=1}^{X} \Omega_{zw}^{q} \leq \sum_{w=1}^{M} R_w$, R_w is the capital restriction for warehouse $w \in \hat{W}$

We assume that the demand is stochastic. For the generality of the model we will formulate the problem considering two stochastic processes: a geometric Brownian motion (assumption done also by Bengtsson, 2001; Tannous, 1996) and mean reversion. Different techniques will be used to solve the objective formula.

- When demand follows a geometric Brownian motion, the process can be presented as:

$$dD \equiv \alpha D dt + \sigma D dz \tag{B.4}$$

Where: $dz = \varepsilon(t)\sqrt{dt}$; $\varepsilon(t) \approx N(0,1)$; $\alpha =$ instantaneous drift; $\sigma =$ volatility; $dz =$ increment of a wiener process and $\varepsilon(t)$ is a serially uncorrelated and normally distributed random variable.
To compute the problem will use the binomial model, assuming that inventory follows a binomial multiplicative diffusion process.

Second, considering that the demand can face sudden changes, we will assume that the demand follows a mean reversion process (MRP) with jumps. The demand is described using the following equation:

$$dD = \kappa\left(\overline{D} - D\right)dt + \sigma D dz + \overset{j}{\Phi}\, dq \tag{B.5}$$

Where: $dz = \varepsilon(t)\sqrt{dt}$; $\varepsilon(t) \approx N(0,1)$, κ is the speed of reversion, $\overline{D}$ is the long term mean, σ is the volatility of the process; $dz =$ increment of a wiener process; where $\varepsilon(t)$ is a serially uncorrelated and normally distributed random variable and Φ^{j} is the jump size, with distribution dq (Poisson), for jumps occurrence. Jump size is modelled as a random variable.

To compute the problem when demand follows a mean reversion we will use the Monte Carlo simulation technique.

V. RESULTS

We used a manufacturing company to test our model. The company persecutes its operations using four manufacturing departments and two distribution platforms. The production and manufacturing take place in plants, which supply customers through finished products' warehouses. Stages are represented in Fig. 1.

Figure 1: Company network representation

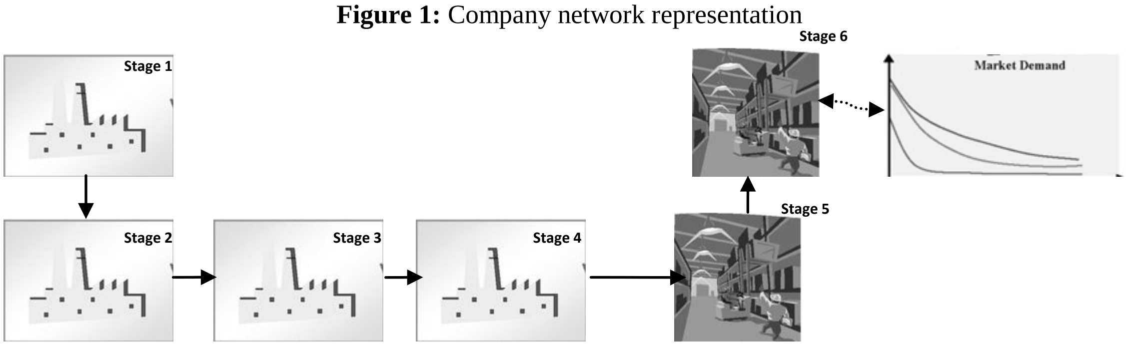


Figure 2: Demand representation using mean reversion for high and low volatility, high and low reversion and with or without jumps

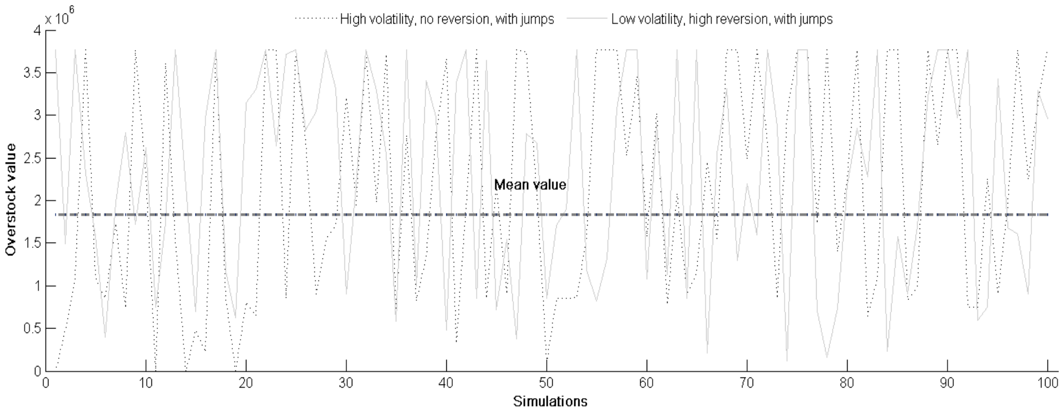


Fig. 2 refers to historical demand behaviour. Using the analysis of historical data we conclude that mean reversion is the best demand process design to be considered.

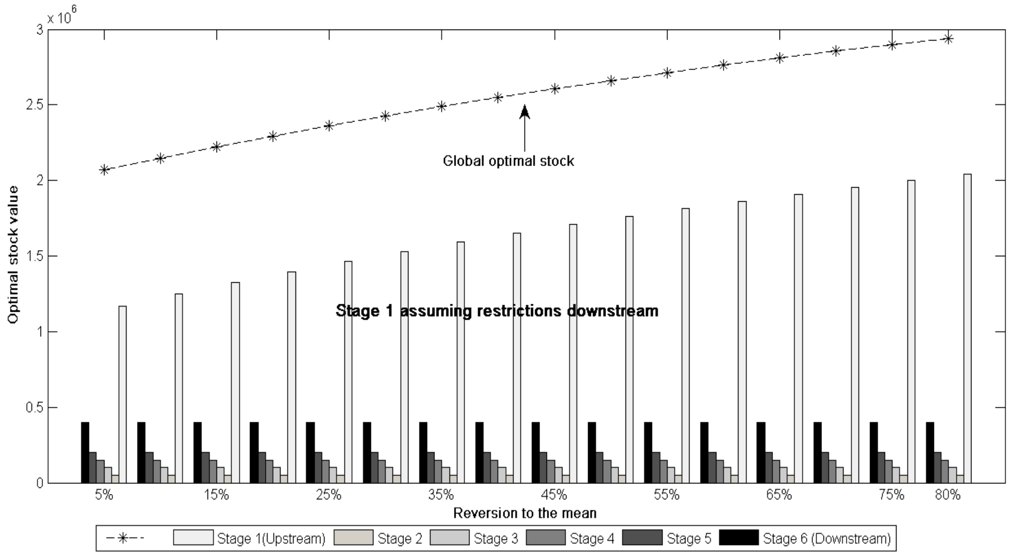
The criteria used by the company for items inventory classification results from the combination between the traditional ABC's classification, based on the turnover to split the items into three categories (fast movers, movers and slow movers); the segmentation (e.g. private labels) and the product's life cycle. We refer to the importance of the product's life cycle in inventory management (Ahiska & King, 2009), mainly in three states: the introduction, the end of maturity (decline) and the terminal phase (e.g. Ballou, 1999; Wiersema, 2008). The company assumes "A's" as the terminology for those items representing more than 80% of the gross sales value. These items follow a make to stock procedure, depending on the existing push or pull strategy and they are defined as "fast movers". "B's" for items that fulfil the gross sales value gap between 80% and 95%. They follow an assembly to order procedure, based on available components, in stages where standardization is possible. They are defined as "movers". "C's" is the name for the items with a low rotation, they are used to promote sales of A's or B's items (mix attraction) and are stored in small batch quantities. They are identified as "slow movers". "Sp's" for those items that are assigned to one client or market segment, nevertheless the use of a specific or shared distribution channel and their stock risk tends to infinitive. They are defined as "specific products" (niche oriented). "N's" is the name for the new items identified as "new products" or "phase-in products", with a high risk exposure. "P's" is the designation of the items that are in the end of the maturity stage, where there should be a preparation of the tools to allow a minimum phasing-out cost. For these items, risk is a variable with high probability to occur. They are considered as "products with potential risk". O's for the items in the "death" stage with constant risk.

The results comprise six major scopes: (1) the effect of demand behaviour on multi-stage optimal stock value; (2) the influence of lead-time changes on multi-stage optimal stock value; (3) the influence of service level changes on multi-stage optimal stock value; (4) capital restrictions on inventory value and (5) the influence of non-optimal stock values. (6) An additional scope is related with the influence of the network design stocking points on stock value.

(1) Effect of demand behaviour on multi-stage stock value.

We tested the effects of changes in reversion to the mean, considering restrictions in each stage invested capital.

Figure 3: Effect of changes in reversion to the mean on the optimal stock value

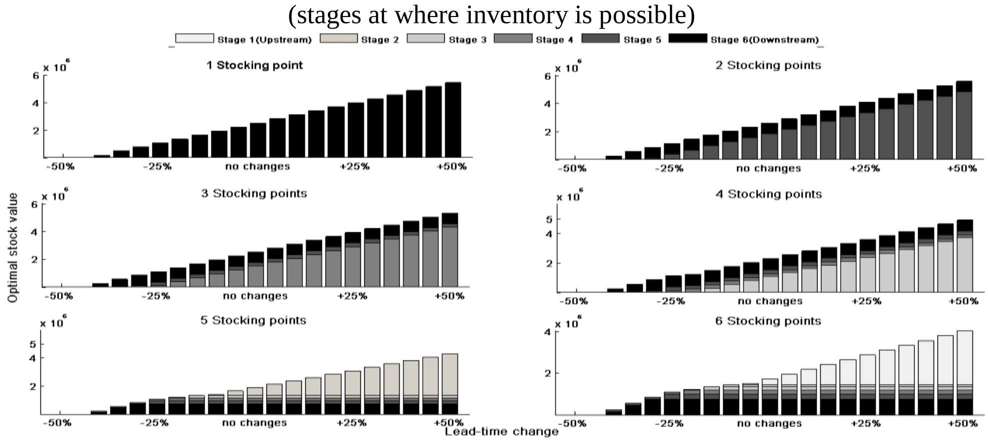


Restrictions in stock level by each stage as follows: stage 6 – 400 000 €; stage 5 – 200 000 €; stage 4 – 150 000 €; stage 3 – 100 000 €; stage 2 – 50 000 €. Demand jumps = 54 000 sqm (positive or negative).

Analysing the results in Fig. 3 it can be seen that when changing the reversion to the mean, an increase on the actualised stock is observed. This is valid for any of the stages considered but, due to restrictions in invested capital, the stock need is more intensive in the most upstream stage; in our case, in the agglomeration plant.

(2) The influence of lead-time changes on multi-stage stock value.

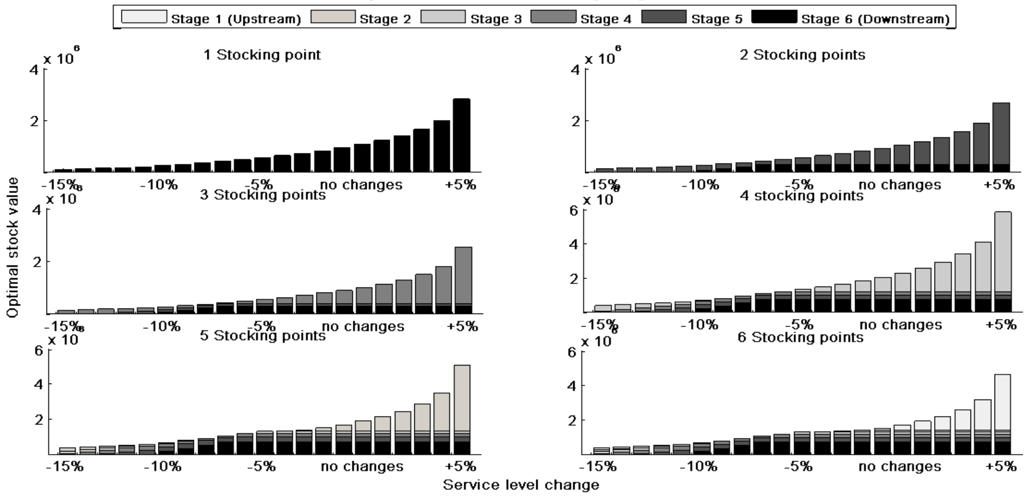
Figure 4: Effect of changes in lead-time on the optimal stock value, considering different stocking points (stages at where inventory is possible)



Restrictions in stock level by each stage as follows: stage 6 – 750 000 €; stage 5 – 250 000 €; stage 4 – 200 000 €; stage 3 – 150 000 €; stage 2 – 100 000 €. Demand jumps = 54 000 sqm (positive or negative). κ = 0,40; σ =0,35

As it can be observed in Fig. 4, that the lead-time reduction, caused by a probable efficiency increase, results in stock decrease. This is partially explained by the increment of rotation in the planning time frame. Increases in lead-time originate higher stock needs. As the network is composed by more available stocking points, the stock tends to decrease, which is consistence with the decrease in the upstream stages' costs.
(3) The influence of service level changes on multi-stage stock value.

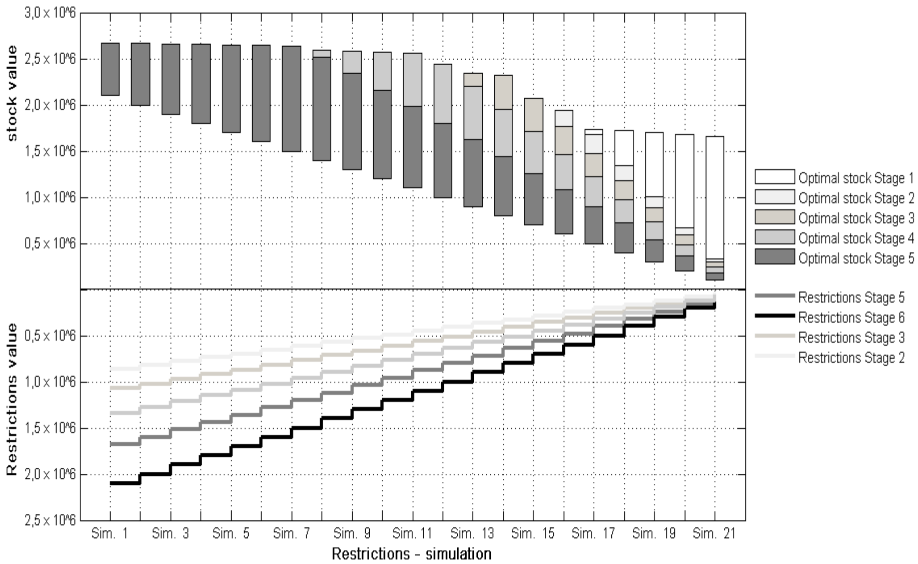
Figure 5: Effect of changes in service level on the optimal stock value, considering different stocking points (stages at where inventory is possible)



Restrictions in stock level by each stage as follows: stage 6 – 750 000 €; stage 5 – 250 000 €; stage 4 – 200 000 €; stage 3 – 150 000 €; stage 2 – 100 000 €. Demand jumps = 54 000 sqm (positive or negative). κ *= 0,40;* σ *=0,35*

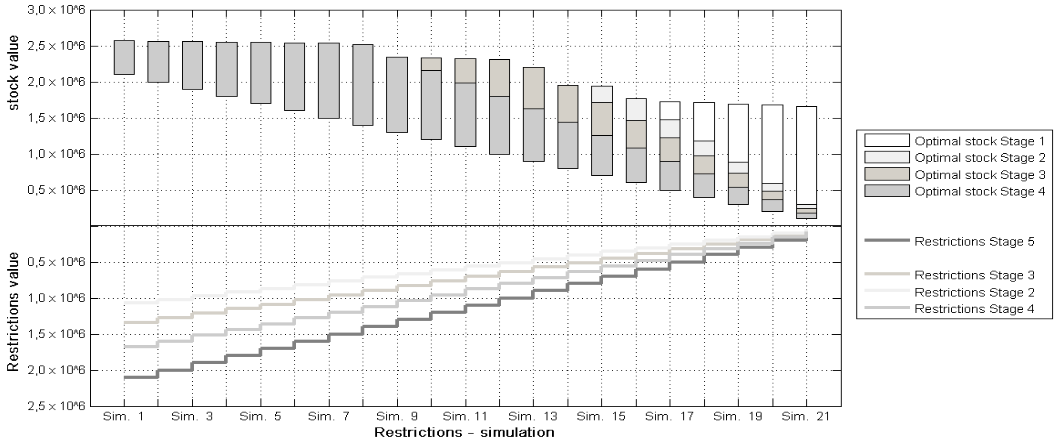
Accordingly to the results observed in the former Fig., the optimal stock value is more sensitive to changes in service level when there is only one possible stocking point. This is essentially explained by the increase in risks. Thus, it was considered interesting to analyse the impact on the stock value caused by changes in the service level but also in the number of stocking points, whereas they are downstream or upstream the supply chain. As simulations where done on the number of stocking points it appears to be clear the concentration of stocks in the upstream stages of the chain, where the incorporated costs are lower.
(4) Effects of capital restrictions on optimal stock value.

Figure 6: Effect of restrictions in five stages



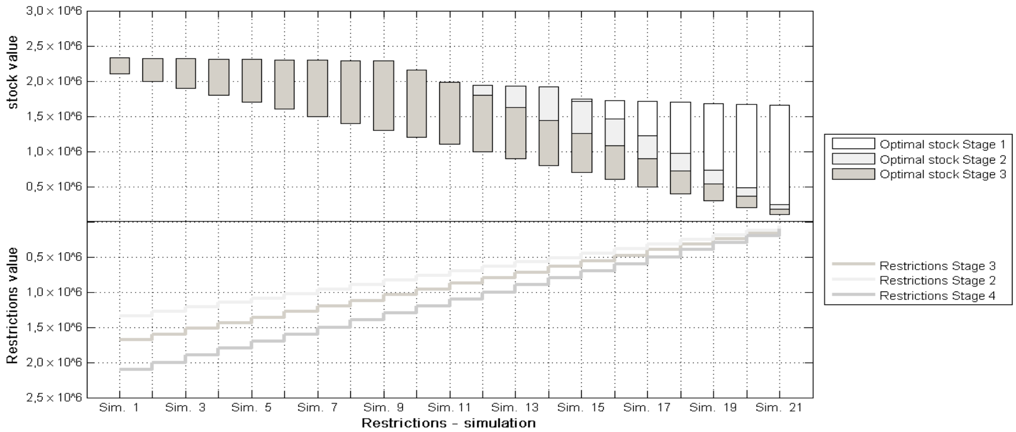
Demand jumps = 54 000 sqm (positive or negative). κ *= 0,40;* σ *=0,35*

Figure 7: Effect of restrictions in four stages (no optimal stock in stage 6).



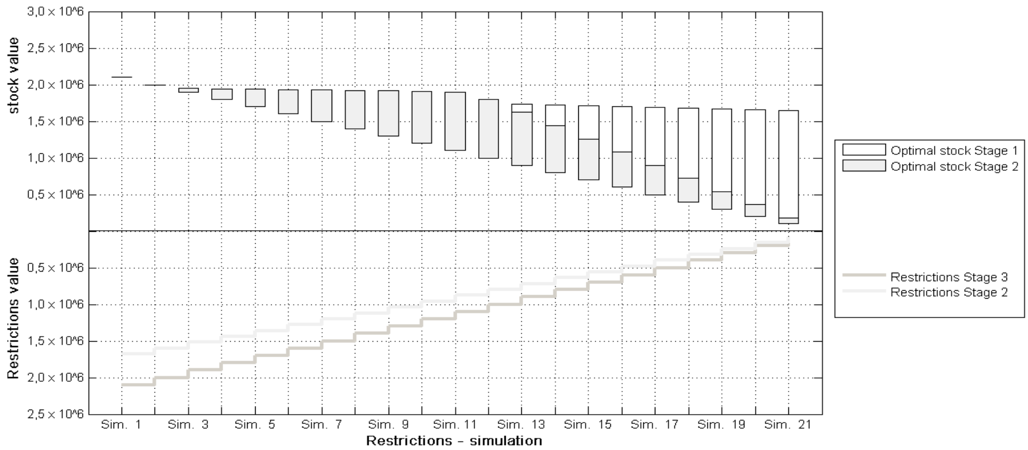
Demand jumps = 54 000 sqm (positive or negative). $\kappa = 0{,}40$; $\sigma = 0{,}35$

Figure 8: Effect of restrictions in three stages (no optimal stock in stage 5 and 6)



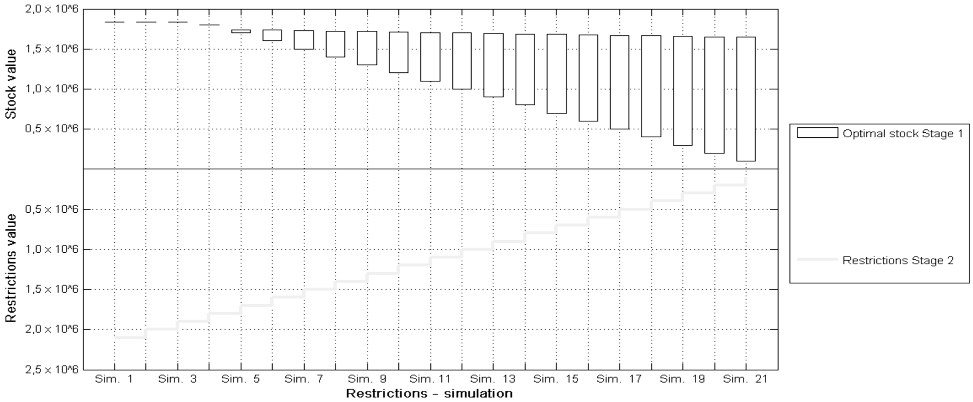
Demand jumps = 54 000 sqm (positive or negative). $\kappa = 0{,}40$; $\sigma = 0{,}35$

Figure 9: Effect of restrictions in two stages (no stock in stage 4, 5 and 6)



Demand jumps = 54 000 sqm (positive or negative). $\kappa = 0{,}40$; $\sigma = 0{,}35$

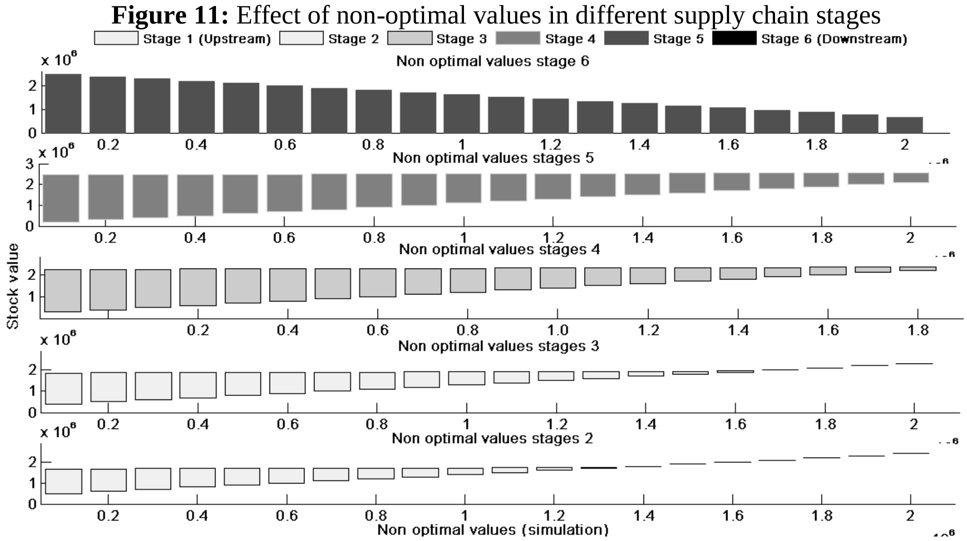
Figure 10: Effect of restrictions in one stages (the only place to put optimal stock is on the stage 1 - upstream)



Demand jumps = 54 000 sqm (positive or negative). $\kappa = 0{,}40$; $\sigma = 0{,}35$

As it can be notice in Fig. 6 to 10, restrictions affect the optimal stock value. Restrictions affect the calculation of the optimal value as we impose maximum stocks, which can be different (less) than the optimal stock according the model to that stage. It is also relevant to emphasize that the concentration of stocks in upstream stages (intermediate stocks on the plants) tends to decrease the inventory value. The interpretation of these results can be linked with the concept of premium as it is considered in real options theory. The optimal stock can be considered an asset that will result in future sales; thus, the value of such asset depends on the time required to transform stocks into effective sales. In this line of thinking a higher time flow decreases the premium value, in our case, the optimal stock value. On the other hand we can use the cost and risk theory to justify that stocks in upstream stages are less risky and less costly (low incorporation of resources).
(5) The influence of non-optimal stock values.

Figure 11: Effect of non-optimal values in different supply chain stages



Demand jumps = 54 000 sqm (positive or negative). $\kappa = 0{,}40$; $\sigma = 0{,}35$

Fig. 11 presents different scenarios for non-optimal stock values that can result from unbalanced supply chains, which is normally consequence of the absence of a single authority or to the lack of available information within the chain partners. We simulated non-optimal values for each stage that is replaced by a fixed amount of 100 000 € in the following computation in the immediately upstream stage. Non-optimal values or distortions on the supply chain have a more significant effect on the downstream stages. Fig. 11 shows the effect on the upstream stage of a non-balanced value. Despite our conceptualisation about a balanced and integrated supply chain, where decisions are done under a single authority and all the information is available, there are different realities. From empirical knowledge, the communication distortion is higher as the distance from the market is amplified. A practical consequence relies on wrong upstream decisions. Based on the results, we support integration and alignment in inventories decision process to protect the supply chain from the market uncertainty.

Table (1): Comparison between different strategies

Traditional Approach Strategy	Agile Supply Chain Strategy	Multi-stage Scheduling Strategy
1-Stock is held at multiple echelons.	1-Stock is held at the fewest echelons.	1-Optimal stock is held at multiple echelons. The intensity in each node is related with demand volatility penetration.
2-Replenishment is driven sequentially by transfers from one stocking echelon to another.	2-Replenishment of all echelons is driven from actual sales/usage data collected at the customer interface.	2-Inventory for upstream stages are dependent of the last downstream stage stock value.
3-Production is planned by discrete organizational units with batch feeds between discrete systems.	3-Production is planned across functional boundaries from vendor to customer, through highly integrated systems, with minimum lead times	3-Production is planned across functional boundaries from customer to vendor, through highly integrated systems, according to the downstream stock level.
4-Majority of stock is fully finished goods, dispersed geographically, waiting to be sold.	4-Majority of stock is held as "work in progress" awaiting build instructions.	4-High upstream stocks implies for a smaller global stock value.

Considering the results and analysing Table 1, there are two main opposite strategies that need to be balanced. One is to hold the stocks in the upstream stages of the chain, where the adding value to raw material is small. The main advantages supporting this idea are the minimization of invested capital value and also additional flexibility, due to the possibility of redirecting a common semi-finished item into different finished items, according to market needs. The other strategy is having a faster service by holding the inventory closer to the market, in order to improve the service level. This idea can have negative impacts on additional invested capital value and on the stock risk, due to a higher number of items.

VI. CONCLUSIONS

In this paper we have presented a model that focus on distribution network stock optimization considering capacity restrictions, number of stocking points, value restrictions and non-optimal values impact.
The contribution of this paper is to provide a new modelling framework for supply chain network scheduling issues and to study how capacity, value, integration management and design restrictions cope with stochastic demand. Accordingly, we simulated changes impact on a distribution network design problem. The results demonstrate the importance of flexible distribution networks and integrated communication and management practices.

This research focused on supply chain network issues in the context of global trade. Several scenarios were considered based on various network configurations and restrictions. This model provides a tool for the logistic decision makers, enabling them to optimize decisions related to scheduling problems while integrating issues of market uncertainty and net resources restrictions impact. At the end we promote an interdisciplinary model where logistic decisions coop with management financial tools.
We believe that models such as this can play a particularly important role in guiding the overall operations of target-scale manufacturing and distribution networks at longer-term planning levels. We believe that the implementation of global profit maximization models represents a potentially significant unrealized opportunity worthy of serious consideration by many firms.

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