Lean Supply Chain Planning: simulation of Lean techniques integration

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Abstract:

Lean Supply Chain (LSC) has become a strategic configuration in order to satisfy customer’s expectations efficiently and effectively. LSC concept is the implementation of Lean principles and techniques outside single company boundaries, creating the flow and making SC reacting instead of foreseeing. Supply Chain Planning (SCP) is a part of SCM management strategy that allows managers to align operations of different companies and so improve operations efficiency and effectiveness. Lean Supply Chain Planning (LSCP) is a new SCP model that is growing interest among both academics and practitioners, but it is not well studied yet. This paper aims at providing a theoretical and practical guidelines about Lean techniques implementations impact in SCP. To reach it, a Discret-event-simulation (DES) simulation model of a three-echelon and multi-product supply chain has been set. This research focuses on three principles of Lean production: identifying the value, creating flow to the customer and pull. The results achieved demonstrate that LSCP techniques have a positive impact on inventories levels and in particular, they demonstrate synergy among techniques so that total benefit is greater than the sum of benefits of single technique implementations

Keywords: Supply Chain Planning, Inventory Management, Lean, Production Control, Kanban;

Introduction

Nowadays, competition moved from business organization level to supply chain cause of strong turbulences, demand uncertainty, product life-cycle reduction and globalization (Mula et al. 2010). Furthermore, modern dynamic market forces supply chains to be flexible and to be able to quickly re-design their plans. In this context, the aim of Supply Chain Planning (SCP) is to satisfy SC final customers minimizing the overall supply chain costs. SCP governs production control and inventory management tasks in a SC and during the years, many SCP models have been developed. However there is not a model that resulted the best and there is still a great gap between theory of SCP and practical application of theoretical models developed (Jonsson & Holmström 2016). On the other hand, Lean management is an approach that is becoming more and more popular among managers for its struggle against wastes. Lean management gives a different approach to operations and it has been demonstrated that company can reach great results following Lean principles (Womack et al. 1992). Lean Management has become a strategic approach that allows operations to satisfy customer’s expectations efficiently and effectively and, at the same time, making the system responsive (Pavnaskar et al. 2003). This concept is founding rapid and wide diffusion among supply chains because it could improve their performances and guarantees competitive advantage achievement. However, there application of Lean in SCP planning task is an uncharted environment that has not been mapped yet (Jasti & Kodali 2015). Lamming (Lamming 1996) and Liker (Liker & Choi 2004) studied Lean Supply Chain Planning (LSCP) and found that practices used were: levelling production schedules, a disciplined system of delivery, handling mixed-load transportation, small-lot deliveries, encouraging suppliers to deliver only what assembly plant needs, helping supplier to develop their capabilities. In a similar more recent work, Martinez-Jurado and Moyano-Fuentes listed a number of practices in SCM that differentiate Lean SCs from other SC management approaches (Martínez-Jurado & Moyano-Fuentes 2013). In particular practices related to LSCP are: Supplier development program, frequent communication and open-door programs, very frequent deliveries, small supplier base, low vertical integration, a strict process for quality attitude. There are few case studies of Lean application in planning scope, and further very few quantitative data about impacts of Lean planning implementation. A case study in semi process industry have been done by Pool (Pool et al. 2011): authors implemented production levelling and setup improvements reaching stock reduction and service level increasing. Another case studied in Ford Motor company have been carried out by Wee and Wu (Wee & Wu 2009). Authors set a Lean SC in the company plant and implemented pull (with Kanban system), SMED and TPM reaching great results. In another study, Swenseth and Olson studied the impact of Lean continuous improvement principle in SCP and found that pursuing Lean approach leads to greater advantages in the long-term prospective (Swenseth & Olson 2016). Application of Lean principles in SCP results an interesting argument but the knowledge about this topic is far from being completed (Hu et al. 2015). This paper aims at evaluating impact of Lean SCP techniques and analysing in-depth impact of their integration in a Lean SC system. Section 2 presents the experimental design of the simulation study conducted. Section 3 describes results obtained from the simulation work. Section 4 concludes with an overview and analysis of the results.

2. Experimental design

A simulation study has been set up to improve our understanding of lean supply chain planning. Simulation tool is the most useful solution to support modern and complex SCP issues, because of its ability to analyze multiple "what-if" scenarios with different operating variables, in a short time and with reduced costs (Terzi & Cavalieri 2004). The model used in this simulation study has been developed through a Discrete Event Simulation software (Rockwell Arena) and it is kept as basic as possible to avoid any noise that might cloud the sight on causes and effects. This simulation work continues the research work carried out by Rossini and Portioli (Rossini & Staudacher 2016b; Rossini & Staudacher 2016a).

2.1 The SC model and the experimental parameters

The simulation model represents a three echelons supply chain composed by four suppliers, a manufacturer and a retailer, as in the figure 1. 24 different products compose variety managed by the SC and they are distributed in 4 product families. Every supplier provides one product family for the SC and has one resource to process its set of products. Manufacturer has four different resources working in parallel and each resource is able to process all product types. Suppliers and manufacturer stages have finite production capacity. Both have an average capacity saturation equal to 80%, distributed in 70% processing time and 10% set-up time. For the aim of this study it has been supposed that production systems are not affected by failures. Retailer is the most downstream stage: it fulfils only distribution activities in order to satisfy final customer demand without processing any item. Suppliers and manufacturer have an inbound and an outbound warehouse, the retailer is a warehouse itself. It is assumed that suppliers inbound buffers store an infinite numbers of items. Transportation capacity for shipping items from one stage to downstream is unlimited and the lead-time to transport an item to the next stage of the supply chain is deterministic and equal to two days. Less than truck load (LTL) transportations are allowed. All these assumptions are common in inventory control literature (Kwak & Gavirneni 2011; Datta & Christopher 2011). Everyday final customer demands finished product to the retailer and the retailer has to satisfy the demand in Make-To-Stock logic. The retailer has to provide before the shipment time (basically before the end of the day) the demanded pieces. If retailer does not satisfy the demand there is the stock-out and so the back-log of the order. The service level of the SC is measured by the mean of the service levels of the single warehouses. It is verified that each single service level is inner of a range centred on the mean. The single warehouse service level is the ratio between the number of days of stockout and the overall number of days in the simulated period. The warehouse is in stockout whether it has not handled all the orders at the end of the day. This research work tested the supply chain performance of different service levels. The simulation was run for a period of 2050 days or 410 weeks with the first 50 days as the initialization period. Statistics coming from initialization period were not used in the results.

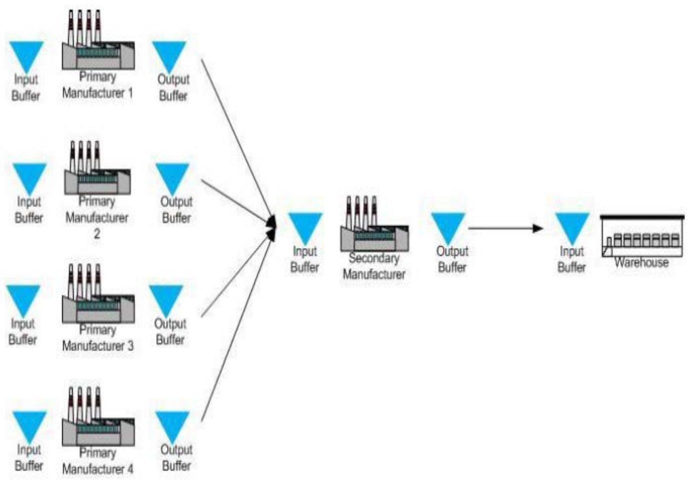

Figure 1 – SC structure

2.2 Lean SC Planning techniques (exp. variables)

This research work aims at understanding how a supply chain can take advantage on its resources implementing lean techniques and at analysing impacts and possible benefits stemming from better productive resources exploitation in the multi-echelon and multi-product supply chain. There are three techniques tested in this simulation work: setup time reduction (STR), batch-size reduction (BSR) and dedication of a production resource to a flow line (DRL). These three techniques are coherent with Lean principle of identifying the value for customers and making it flow. All these techniques are tested for one resource of Manufacturer: the represented situation is the investment of the company in a new machine that is more flexible than already present ones or the investment for improving a part of the set of resources present in the company. The aim of this study is to understand the better way to exploit this opportunity for the company and the SC. When STR is implemented, the setup time is shorter when the resource changes product type. When BSR is implemented, the average batch size (production or order) is reduced. When DRL is implemented, the resource processes only products provided by one supplier (that for this study will be supplier-1).

3. Results

This section describes and discusses the results of the simulation study focusing the attention on the average inventory level kept in the different warehouses of the SC.

3.1 Effects of STR

Reducing average setup time, new capacity is made available. Keeping same batch size and halving setup time on a resource, half of machine saturation related to setup is released and daily capacity is increased. This surplus of production capacity gives a greater capability to the manufacturer to react. Therefore, it is obvious to state that STR leads to performances improvement. But, as showed in the table 1, the impact on the whole SC is not so great. This could be explained by two factors: first one, the starting saturation of 80% is not so high, so the effect of free more production capacity has not a great impact on reducing queues; second one, STR affects only manufacturer capacity, supplier does not benefit in any way of this improvement.

Table 1: effect of STR

	SC	Supplier	Manufacturer
Inv. level	-0,3%	0%	-0,6%

3.2 Effects of BSR

Following only the path of batch size reduction without reducing set-up time leads clearly to disadvantages and over certain thresholds is impossible also. Implementing BSR increases production capacity saturation and it is not possible overtake 100% saturation limit. BSR is a technique that is possible to pursue only when even STR is implemented in order to not oversaturate the production system. Hence, an analysis of the impact of only BSR implementation has no sense in this research work.

3.3 Effects of DRL

Simulations carried out in this case consisted of dedicating a manufacturer resource to production of only one product family. No reductions of set-up or batch size have been implemented. As shown in figure 2, despite being small, there is an overall performances worsening. For lower service levels, the inventories grow between 2,5% and 5,5%, while for higher service levels the inventories decrease by less than 1%. This negative overall impact is explained by the reduction of system's flexibility because of dedicating rigidity.

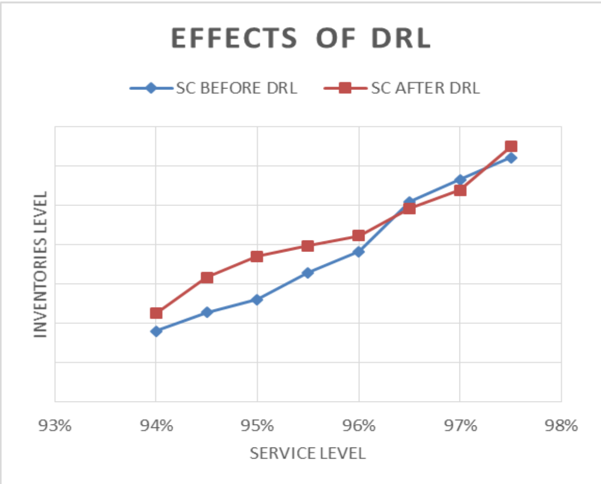

Figure 2 – effects of DRL

3.4 Effects of integration of Lean techniques

After having studied the effects of each single technique, combined effect of STR, BSR and DRL has been simulated. According to this context, an improved resource has setup time reduced, batch size reduced and this resource is dedicated to the product family-1 (consequently to the Supplier-1). Results achieved by the combination of the three techniques are relevant: as showed in the table 2, the average inventory level related to supplier-1 product family is decreased more than 20%. The performance of SC is also improved with an overall inventory level reduction of more than 2%.

Table 2: effects of Lean techniques integration

	SC	Supplier	Manufacturer
Total	-2%	+4%	-8%
Family-1	-24%	-26%	-20%

The combination of Lean techniques led to two main effects. First effect is a great reduction of inventories for family-1 thanks to the levelling of the flow and the availability of a greater flexibility. Second effect is a little worsening of inventories related to other product families, caused by a greater rigidity of the system (from 4 resources to 3 resources).

4. Conclusion

This study has addressed one of the most recent practical issue in SC planning: how implement Lean management in planning task and how it is possible to apply Lean principle in SCs (Jasti & Kodali 2015; Swenseth & Olson 2016). It has focused on a three-echelon and multi-product supply chain and it has analysed in depth SC inventory level. Three techniques have been tested and relevant insights are provided. A first main insight is that pursuing lean principles is not just to take a technique and to insert it in a system. Simulations results showed that single technique implementation leads to small results or even to a worsening of performances. To reach relevant results integration/combination of more techniques resulted necessary. This can be a reason of why Lean management finds some resistance by companies to be implemented. Companies do not apply Lean because of necessity of long-term point of view and of a broader application of Lean techniques inside the whole system. Pursuing only some aspect of Lean management is faster and cheaper but does not provide great benefits. The integration among Lean principles is the key factor for the success of Lean approach. A second interesting insight is that distribution of benefits of Lean techniques implementation is not linear. As showed in the table 2, manufacturer is the player that implements Lean techniques but both supplier and manufacturer receive benefits and supplier's benefits are even greater than manufacturer's. Even this fact can be listed as one of the reasons of why Lean implementation is not so common in industry. Lean approach focuses a lot on the holistic point of view. A company that wants to pursue lean approach cannot look only its own performances and has to look out even of its boundaries. This paper represents an important step in applying Lean management in SC planning. However, future research should build on this contribution. First, future improvements in understanding how performances change when there are one or more players that apply lean techniques. How Suppliers and Manufacturers can align their improvements target in order to improve overall SC performances is an interesting aspect to analyse.

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