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Exploring the link between lean practices and sources of uncertainty in Supply Chain

Claudia Del Monte¹, Matteo Zanchi¹ and Paolo Gaiardelli¹ [0000-0002-2207-3628]

¹ Department of Management, Information and Production Engineering,
University of Bergamo, Viale Marconi 5, Dalmine (BG), Italy
c.delmonte@studenti.unibg.it,
matteo.zanchi@unibg.it, paolo.gaiardelli@unibg.it

Abstract. In an ever-changing environment, supply chains face countless risks generated by different sources of uncertainty. The adoption of lean management initiatives has been recognized as a viable and effective way for dealing with these uncertainties. However, since constant and rapid change of variables affecting supply chains risks nullifying or diminishing the potential benefits of lean initiatives, identification of proper lean practices emerges as essential to address their successful implementation. On these premises, this study proposes a model linking lean management practices with different forms of supply chain uncertainty. The model, built upon an analysis of the literature, is designed to help managers and practitioners in identifying and prioritizing lean actions to address issues within their supply chains.

Keywords: Lean Management, Supply Chain Management, Uncertainty, Literature review.

1 Introduction

Lean Management (LM) has been recognized over the years as one of the most promising approaches to help managers in controlling and managing complexity of a Supply Chain (SC) [1]. The reason why adoption of lean principles has gained attention in Supply Chain Management (SCM) resides in their ability to reduce the lead time from order receipt to customer delivery through the elimination of wastes and the simplification of processes [2]. Indeed, by acting on process instability, rigidity and opacity through standardization, implementation of a pull logic and promotion of collaboration, LM methods foster the creation of more responsive, flexible and efficient SCs [3].

Although LM plays a key role in the control of SCs, scientific studies are still lacking in providing a clear view of what lean actions should be taken to effectively deal with uncertainty in SCs. This critical issue is amplified by the difficulty in determining which practices are the most appropriate to respond to a particular type of uncertainty. Indeed, the increasing complexity of SCs, characterized by articulated configurations, rapid changes in customer choices and ever tighter timeliness, often makes ineffective the adoption of many lean approaches, based on fixed work cycles and

times and suitable for stable production [4]. Therefore, identifying the most appropriate LM practices for uncertainty management in SC would help lean managers and practitioners in better identifying and prioritizing their actions to address critical issues characterizing SC operations. To answer this problem, this paper proposes a map of the main LM practices to address sources of uncertainty in SCs. Consistently with [5] the sources of uncertainty in SC are mapped around 14 categories, for each of which a set of suitable LM practices, derived from an extensive analysis of literature and grouped in accordance with [6], is proposed. The achieved map provides a structured and comprehensive overview of the relationship between uncertainty and LM practices.

2 Methodology

This study is based on an extended analysis of the literature on SCM and its issues and LM practices. In particular, Web of Science and Google Scholars were the two databases used to collect relevant papers on the topics under exploration, considering a time frame restriction of the last ten years. Among the results, only English papers with full-text availability were taken into consideration. A forward snowballing research was paired with the backward citation analysis to avoid any weaknesses characterizing retrospective research. As a result of the adopted forward-backward snowballing analysis, 93 journal papers were finally reviewed. In addition, the research was deepened by consulting textbooks on Lean philosophy, Lean Management in operations and Lean Supply Chain.

3 Literature analysis

According to the purpose of the study, the literature analysis was built around two main parts. The first part proposes an analysis of the current studies concerning sources of uncertainty in SC, while the second part reports a description of lean practices for uncertainty management, extrapolated from the case studies available in the scientific and managerial literature.

3.1 Sources of uncertainty in SC

A SC refers to all the parties involved, directly or indirectly, in satisfying a customer's demand for a product or service [1]. It consists of multiple business partners who work together and collaborate by sharing information, material and financial flows. Therefore, a SC is usually faced with a considerable number of exogenous and endogenous drivers of complexity originating from different sources which can arise from network, process, range product, customer, supplier, organizational and information complexities. The latter can be associated with fourteen sources of uncertainty which in turn can be split into three main groups [5]: i) uncertainties originating from the focal company; ii) uncertainties arising within the SC; iii) uncertainties external to

the SC. While uncertainties originating within the focal company and its partners are generally manageable, external uncertainties are often out of direct control. The list of SC sources of uncertainty is reported in Table 1.

Table 1. The sources of uncertainty in SC [5].

Category	Source of uncertainty
Uncertainties coming from the focal company	1. Product characteristic
	2. Manufacturing process
	3. Control/chaos
	4. Decision complexity
	5. Organizational/behavioral issues
	6. IT/IS complexity
Uncertainties internal to the SC	7. End-customer demand
	8. Demand amplification
	9. Supplier
	10.Parallel interaction
	11.Order forecast horizon
	12.Chain infrastructure and facilities
Uncertainties external to the SC	13.Environment
	14.Disruption/natural disasters

3.2 Lean practices for uncertainty management

Several authors have proposed various models that combine the fields of LM and SC. Among others, the 8-pillar model [10] represents a unified Lean Supply Chain Management (LSCM) framework that permits an explicit definition of the set of elements that characterise this field. For its characteristics of completeness, this model can be considered as the best reference model to categorize LM practices for uncertainty management in SC, identified in literature and summarized in Table 2.A, Table 2.B and Table 2.C.

Table 2A. Lean practices for SC uncertainty classified according to the 8-pillar model [6].

Category	Practices	References
Information Technology Management (ITM)	ITM1	Effective and transparency information flow throughout supply chain
	ITM2	Modelling analysis and simulation tools
	ITM3	Computer-aided decision-making supporting systems
	ITM4	Enterprise resource planning system
	ITM5	ICT system (EDI)
Supplier Management (SM)	SM1	Supplier evaluation and certification

Table 2B. Lean practices for SC uncertainty classified according to the 8-pillar model [6].

Category	Practices	References
Supplier Management (SM)	SM2 Strategic supplier development	[6], [7], [9]
	SM3 Supplier proximity	[6]
	SM4 Single source and reliable suppliers or few suppliers	[6]
	SM5 Long-term supplier partnerships	[6]
Elimination of waste (EW)	EW1 Design for x/concurrent engineering	[2]
	EW2 Standard products and processes	[6], [7]
	EW3 5S	[6], [2], [9]
	EW4 SMED	[6]
JIT Production (JITP)	JITP1 More simple lines/re-layout	[10]
	JITP2 TPM	[7], [8]
	JITP3 Levelling the workload	[2], [10]
	JITP4 One-piece-flow	[6]
	JITP5 Pull systems	[9], [10]
	JITP6 Volume flexibility	[6]
Customer Management (CM)	CM1 Customer involvement in design	[1]
	CM2 Continuous evaluation of customers' feedback	[1], [8]
	CM3 Customer flexibility	[6]
Logistic Management (LM)	LM1 Postponement	[5], [6]
	LM2 Continuous replenishment	[6]
	LM3 Shorter planning period	[6]
	LM4 Delivery flexibility	[6]
	LM5 Use of 3PLs for transportation system	[6], [8]
	LM6 Consignment inventory or vendor managed inventory	[6]
	LM7 Effective logistic network design	[6]
	LM8 Consolidated warehouses	[11]
Top Management Commitment (TMC)	TMC1 Responsibility and autonomy	[2]
	TMC2 Cross-enterprise collaborative relationships and trust	[6]
	TMC3 Employee training and education	[6]
	TMC4 Good Decision Support System	[5]
	TMC5 Holistic strategy for integrating system/ org. policy deployment	[6]
	TMC6 Create vision and objectives to lean supply chain	[6]
	TMC7 Nemawashi	
Continuous Improvement (CI)	CI1 Job enlargement	[7]
	CI2 Job enrichment	[7]
	CI3 Six Sigma	[7]
	CI4 Jidoka	[8]
	CI5 TQM	[8]
	CI6 Poka Yoke	[2]

Table 2C. Lean practices for SC uncertainty classified according to the 8-pillar model [6].

Category	Practices	References
Continuous Improvement (CI)	CI7	Cross functional team within the organization
	CI8	Process performance measure

4 Linking LM practices with sources of uncertainty in SC

Once the main sources of uncertainty in SCs were defined together with the list of lean practices that can intervene to mitigate their effects or reduce their occurrences, a relationship map was built, as summarized in Table 3 and briefly described in the following.

Product characteristic. The adoption of design for X and concurrent engineering support cooperation between all parties involved in product design, help all participants achieve a better understanding of costs and time for product realization [2], while the implementation of postponement allows to produce variants only when more information is available. By implementing continuous replenishment and shortening the planning period, more frequent control is ensured, avoiding uncertainty in production volumes [5]. Moreover, the adoption of a short and integrated SC according to FIFO lane logics can ensure faster and more timely deliveries. Finally, postponement and modularisation allow production to be differentiated only when the customer's demand is better known [5].

Manufacturing process. Adoption of Total Productive Maintenance (TPM), for the development of preventive maintenance policies [8], implementation of streamlined re-layout of production lines [10], which allows to prosecute manufacturing processes on alternative lines in case of breakdowns, and introduction of job enlargement and enrichment enable flexibility in the redistribution of workforce. Lean six sigma is the recommended approach to deal with process variability, by controlling problems related to the standard deviation of processes [7]. Jidoka, which considers human involvement in automated processes, and Total Quality Management (TQM) represent viable ways to further eliminate wastes [8]. Moreover, the creation of a comfortable working environment and assignment of responsibilities to workers can help increase job satisfaction and, accordingly, reduce the risk of unproductivity. SDCA (standardize, do, check and act) practices are centered on the creation of stability [10]. Lastly, 5S is helpful in creating a safe and ergonomic work environment [2].

Control chaos uncertainty. One-piece flow principle and SMED practice, which lead to a reduction of lot sizes, allow to process smaller and more frequent orders [10]. The criticalities resulting from SC control systems, like wrong control rules and mismatch in the ICT system, can be mitigated by simplifying the information flow using information and communication technologies, such as enterprise resource plan-

ning (ERP), web interface devices for data exchange as extensive markup language (XML) and electronic data interchange (EDI) systems [5]. If synchronization is not possible, a good tool to transmit reliable information on effective consumption and to create an automated mechanism of coordination is represented by Kanban [2]. Meanwhile, sensor and radio frequency identification technologies represent additional tools that ensure transparent flows of information in the network [5]. Finally, the adoption of standard procedures simplifies the upstream work and allows the focal company to receive the information from SC partners in the required manner.

Decision complexity. Setting up cross-functional teams to define company objectives, defining a process-oriented system of goal setting and incentive allocation represent effective ways to avoid conflicting objectives [6]. Moreover, capacity constraints, for both production and logistic sectors, can be reduced by collaborating with the customer, to redefine service agreements, or with other support companies, through extra capacity ‘borrowing’ agreements. Administrative issues and decision policies can be dealt by redesigning decision procedures to eliminate unnecessary process steps.

Organization/behavioral. Implementing standard procedures, eliminating unnecessary decision process steps, and linking employee performance objectives with SC objectives can reduce the uncertainty due to political influence in the decision-making process. These practices, along with Nemawashi practice, which consists of a system of consensus building that first seeks informal approval of initiatives before the beginning of the formal process [2], may also reduce uncertainties associated with general behaviour where different predispositions can lead to disruption in the SC.

End-customer demand. Postponement and process flexibility in terms of production volume, may cope with seasonal demand variability, while maintaining close relationships with customers to anticipate their needs and earning their loyalty can help in retaining the current customer base, pending to learn from the market leader and adapt to the products offering [5].

Demand amplification. Demand signal processing may lead to unusual high stock levels in the upper region of the SC, which can be reduced by: elimination of functional interfaces to reduce time delays and information distortion (a technique is the VMI); application of time compression of both order information upstream and product transfer downstream; information sharing and tight coordination to enable synchronized planning; shorter planning period to avoid bullwhip effect; postponement to prevent over-reaction to short-term fluctuations in demand; ICT system to facilitate information sharing. Share of production plans and inventory with downstream SC partners can reduce rationing games to order more units than actually needed made from customers. Furthermore, order batching policy can be fought with proper information sharing or, better, by implementing a pull system and one-piece flow logic. In

the end, demand amplification due to price variations that lead to unexpectedly high demand can be solved through collaboration among SC partners along the whole chain.

Supplier. Developing and supporting plans with suppliers or streamlining the SC by vertical integration is necessary to grant that a specific level of service can be met, though this often requires the stipulation of long-term contracts. To deal with availability of supply, instead, agreements should consider guaranteed volume of supplied products. Close coordination to early intercept potential problems and work together on them to find a solution is key. To do so, a supplier ICT system to track the movement and usage of their materials can be used to improve volume flexibility [5]. Finally, selection of certified suppliers or helping suppliers in implementing Lean practices could be an option to get the right quality of supplied products [7].

Parallel interaction. Through reduction of partners involved in a SC it is possible to potentially reduce problems related to parallel interaction between businesses in each tier of the SC and other channels in the network, leading to increased responsiveness to customer orders. Furthermore, a good coordination among chain partners can also reduce the parallel interaction issue, as well as relying on ICT systems to exchange information provides suitable plans and delivery schedules [5].

Order forecast horizon. Increasing the frequency of deliveries to improve forecast accuracy or using computer assisted ordering to manage stock levels at retailers enable short information lead times [5]. Specifically, prove their effectiveness, the adoption of kanban to regulate the material flow dynamically, the use of milk run to ensure high frequency deliveries and the implementation of SMED to reduce batch size.

Chain infrastructure and facilities. Reduction of the number of suppliers to less spread the suppliers across the geographical area, building of production facilities closer to suppliers and customers to reduce shipping time, use of consolidated warehouses and outsourcing logistics, which enable a better schedule of delivery and reduction of transportation costs are valuable ways to manage the uncertainty related to chain infrastructure and facilities. ICT systems like EDI can provide dependable communication with suppliers and customers, while redesigning the chain infrastructure, by outsourcing transportation and distribution to a 3PL provider, enables effective delivery schedule and efficient operations [11].

Environment. Environment uncertainties, including changes in government regulations, can be mitigated by collaboration ruled by the Nemawashi principle. Even macroeconomic issues might press a company to change its plans: in this regard, the availability of production facilities in more countries can provide the necessary flexibility to temporarily switch production to other countries. Finally, to cope with com-

petitors' behaviour, collaboration can be created through horizontal mergers and acquisitions [5].

Disruption/natural disasters. Postponement, availability of production facilities in multiple locations, enabling customer flexibility with suitable incentives may increase customer satisfaction and sales during the disruption period [5].

Table 3A. Linking LM practices to address SC uncertainty

Source of uncertainty in SC	Dimension	LM practices
U1	Product specification	EW1; LM1
U1	Packaging characteristics	EW1
U1	Product lifecycle	LM2; LM3
U1	Product perishability	/
U1	Product variety offered	LM1
U2	Machine breakdowns	JITP1; JITP2; CI1
U2	Variable process yield and scrap-rates	CI3; CI4; CI5; EW1
U2	Changes in employee productivity	EW2; TMC1; TMC2; CI1; CI2
U2	Accidents	CI1; TMC3; EW3; JITP3
U3	Sales order is small compared with batch sizes	LM3; EW4; JITP4
U3	Chaos resulting from SC control systems	JITP5; TMC4; LM3
U3	Inaccurate or poor reports from SC partners	SM1; EW2; CI6
U4	Different goals across functional departments.	TMC5; TMC6; CI7
U4	Capacity constraints	TMC2; TMC4
U4	Uncertainty in long range strategic planning	/
U4	Administrative issues and decision policies	TMC5
U5	General behavior issue	CI8; TMC2; TMC3; MC4; TMC6; TMC7; EW2
U5	Internal politics	TMC7; EW2
U6	IT/IS system unavailability	/
U6	Data/information security issues that leads to uncertainties	/
U6	IT/IS system performance that leads the uncertainty	/
U7	Seasonal demand variability	LM1; LM4; JITP6
U7	Changes in customer tastes	CM1; CM2
U7	Irregular or sporadic events	/
U8	Demand signal processing	JITP5; LM1; LM3; LM6; ITM1; ITM4; ITM5
U8	Rationing game	TMC2

Table 3B. Linking LM practices to address SC uncertainty

Source of uncertainty in SC	Dimension	LM practices
U8	Order batching policy	TMC2; JITP4; JITP5; ITM1; ITM3; ITM4
U8	Price variations	TMC2
U9	The timing of supply	SM1; SM2; SM3; SM4; SM5; ITM1; ITM5
U9	The quality of supplied product	TMC2; SM1; SM2; SM5
U9	The availability of supply	TMC2; SM3; SM5; ITM1; ITM4; ITM5
U10	General	SM3; SM4; TMC2; ITM1; ITM5
U11	General	LM3; JITP5; ITM1; ITM5
U12	The geographic areas	SM3; LM4; LM7; LM8; JITP6
U12	Communication	ITM1; ITM5
U12	Transportation infrastructure	LM7
U13	Political stability	/
U13	Government regulation	TMC2; TMC7
U13	Macroeconomic issues	JITP6; LM4
U13	Societal issues	/
U13	Competitor behavior	TMC2
U14	Natural disasters	LM1; JITP6; LM4; CM3; TMC2

5 Conclusion

Developed around a literature analysis and built upon two reference models, this paper contributes to consolidate the theoretical knowledge in the field of SCM, through a mapping of the LM practices suitable to address specific sources of uncertainty in SC. At the same time, it identifies those areas of uncertainty that cannot be effectively addressed through the use of lean thinking principles, providing important insights into areas of research still to be explored. The provided map is a valuable support tool for managers and consultants to assign priorities and efficiently develop LM action plans to address the distinctive sources of uncertainty in their SC. Being based on a literature study, the work requires further investigation to expand its theoretical view into a more practical perspective. In particular, experts' involvement and case studies emerge as necessary to complete the proposed map as well as to assess the actual effectiveness of adopted lean practices in relation to different industrial and organizational contexts.

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