Using system dynamics approach to examine the impact of ERP and Lean on manufacturing performance

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Abstract

The benefits of Lean manufacturing and Enterprise Resource Planning (ERP) for manufacturing systems have been confirmed in the literature. However, there are continuing debates on the effects of these two systems on the manufacturing performance. Given this trend, this paper aims at quantitatively examining these impacts and offers insights for the managerial implications. A system dynamics approach is used to illustrate how the performance changes under different scenarios using the real data of a case study at the textile and garment industry. The results highlight the role of Lean manufacturing itself and lend support to the view of the inefficiency of ERP system to manufacturing system. A suggestion to build ERP-based Lean system which ERP supports Lean production is made for industry managers to gain the benefits from the ERP system.

Keywords
ERP, Lean, manufacturing, performance, system dynamics.

1. Introduction

"Lean manufacturing" or "Lean production" is acknowledged as a "standard manufacturing mode of the 21st century" (Shah & Ward, 2007) and a philosophy of managerial approaches that helps organizations to cope with the new competitive environment (Shtub & Karni, 2010). Besides, along with the development of Lean production, information systems, Enterprise Resource Planning (ERP) in particular, to provide the information and decision support to the management are also developed (Shtub & Karni, 2010). ERP systems has been also seen as an effective tool for companies seeking efficiency through organizational integration to improve their performance

(Laukkanen, Sarpola, & Hallikainen, 2007; Powell, Riezebos, & Strandhagen, 2013). Lean manufacturing and ERP have received attentions from managers during the last decade (Shtub & Karni, 2010).

However, in the literature, there is an continuing debates on the inherent conflict between Lean principles and IT (ERP in particular) (Bruun & Mefford, 2004). In some cases, ERP and Lean are considered to be unable to mix well (Steger-Jensen & Hvolby, 2008) because while Lean develops a pull system, the ERP system works based on "push" principle (Bruun & Mefford, 2004; Halgeri, McHaney, & Pei, 2010; Riezebos, Klingenberg, & Hicks, 2009). Therefore, ERP is considered as a hindrance to Lean manufacturing (Halgeri et al., 2010; Powell, Alfnes, Strandhagen, & Dreyer, 2013; Powell, Riezebos, et al., 2013).

The current body of existing knowledge still lacks the research of this area (Powell, Alfnes, et al., 2013). Given this trend, the research aims at quantitatively examining how ERP, Lean and ERP-Lean system affect the operational performance of a company. System Dynamics (SD) methodology is used to illustrate how performance changes under different scenarios with real data of a case study at textile and garment industry.

The paper is structured as follows. Section 2 provides an overview of the research methodology. Section 3 illustrates the simulation model with the parameters and scenarios. It then presents the results and discussion in section 4. The paper concludes with future suggestions.

2. Methodology

SD is a methodology and computer simulation modeling technique used to analyze and solve complex problems, with a focus on policy analysis and design through understanding the dynamic behavior of systems (Poles, 2013). This method combines Causal Loop Diagrams (CLD) for representing the feedback structure of systems and the causal relationships among system variables (Sterman, 2000); and Stock and Flow Diagrams (SFD) for obtaining variables in mathematical equations (Mandal et al., 2002). SD modeling is considered to be a useful structural theory for operations management (Corinna Cagliano, DeMarco, Rafele, & Volpe, 2011) and claimed to be able to view different scenarios and consider a number of performance measures for highly complex systems that are related to people as well as processes (Campuzano & Mula, 2011; Ellram, Tate, & Carter, 2007; Kanda & Deshmukh, 2008).

A company which has not yet successfully implemented Lean and ERP is chosen to foresee the future scenarios of ERP, Lean and ERP-Lean application. This is a garment assembling company with the production strategy of make – to – order. The production modality is that the customers are in charge of the transportation costs from the shipping location to the final destination. If the manufacturer cannot meet the shipment date, it must use airship method to meet the delivery date which is not cost-effective. Therefore, delivery-on-time is vitally important for the company. Backlog is the main concern, hence it is considered as the manufacturing performance in this study.

In the current state, this organization has not fully established the ERP system with the missing of Finance and Accounting and Customer Relationship Management (CRM) modules. Although they have electronic systems in place for some functions, each module works separately, performing its own data-processing function and there is no ERP integrated platform. As regards to Lean manufacturing, although Lean is a set of tools related to a cost reduction initiative and a philosophical approach focused on customer satisfaction (Pettersen, 2009), the company has only performed the 5S tool at very first stage. The inefficiency is easily seen in on-site observation where there is a high rate of work-in-process (WIP), defects, or stoppages.

This research was conducted at a garment assembling company from September 2016 to December 2016. Data collection for this study utilized multiple sources of evidence to ensure both the reliability and construct validity for

the study. On-site interviews with managers and observations are used to develop the simulation model. Documentary data for one year from August 2015 to August 2016 are collected and analyzed for input parameters.

Since every company is locked in a supply chain, only through a tight integration between supplier and customer can a company hope to compete successfully (Lenny Koh, Saad, & Arunachalam, 2006). In this study, to observe how the ERP, Lean system and ERP-Lean system affect the performance of the company, the manufacturing supply chain model is built.

3. The SD model

3.1. General structure

The manufacturing supply chain model is built based on the model of Sterman (2000). This is the typical model of a make – to – order manufacturing system with basic functions of material management, manufacturing and customer fulfillment. The researchers modify the simulation model for the case study following the current practices of the research case.

The SFD capturing the model structure and the interrelationships among the variables is presented in Figure 1. The model and associated differential equations are developed using Vensim® PLE, Copyright © 1988-2015, Ventana Systems, Inc.

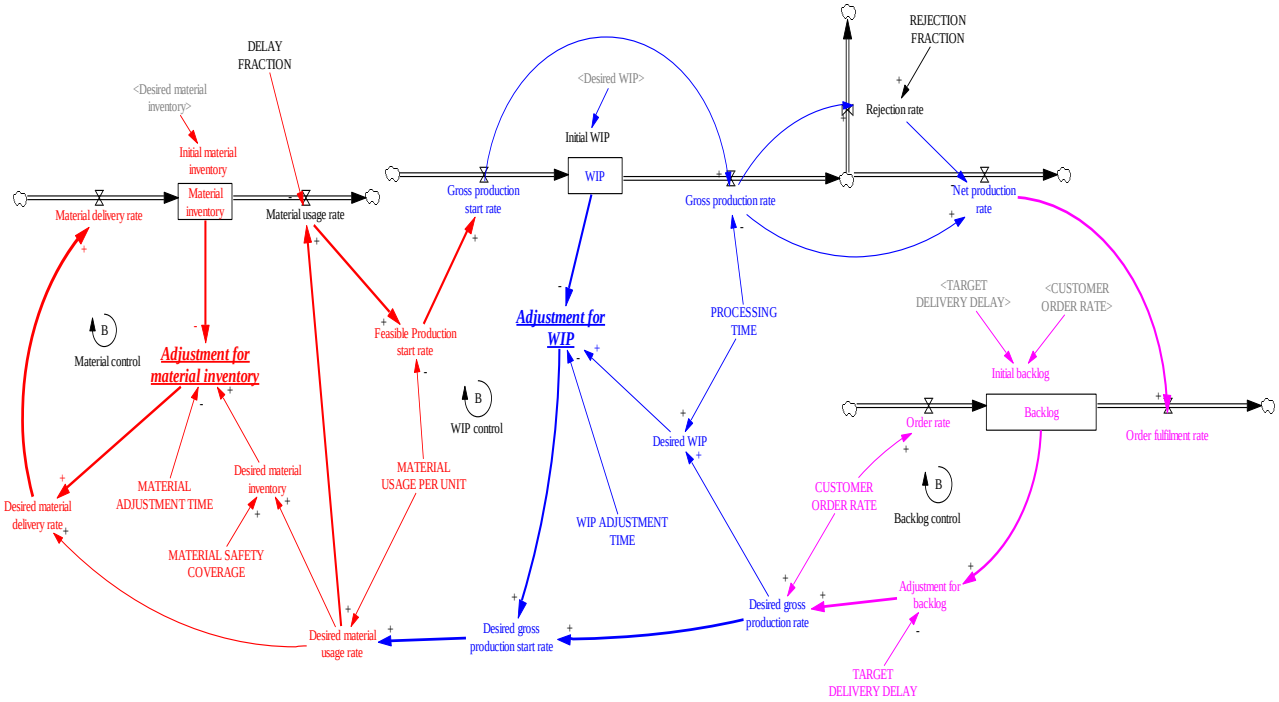

Figure 1: The system dynamics model

On the diagram, the model presents the manufacturing supply chain process with three modules: order fulfillment (presented by pink color), material management (presented by red color) and manufacturing (presented by blue color). The overall polarity of a feedback loop is indicated by a symbol in its center with the "R" sign indicating a positive loop and a "B" sign indicating a negative loop. Stock variables are illustrated by rectangles. Flow rates are pipes with valves that lead into or out of stocks. The arrows also present the relationship two variables with the sign "+" indicating the same direction change and the sign "-" indicating the opposite direction change between them. Auxiliary variables in upper case letters show constant input and those in lower case letters are converters. The auxiliary input variables include *Customer Order Rate*, *Rejection Fraction*, *Delay Fraction*, *Material Usage Per*

Unit, Material Adjustment Time, Material Safety Coverage, Processing Time, WIP Adjustment Time and *Target Delivery Delay.*

Figure 1 illustrates foundation activities of a manufacturing system. Improvement activities and different policies work on improving or changing the value of auxiliary input variables. In this study, it is assumed that there is no breakthrough in the functions of the model rather than changes in parameters of the system.

3.2. Scenarios

ERP is mentioned that it does not to have direct impact on improved firm performance without Lean manufacturing (Ward & Zhou, 2006). Therefore, three different future scenarios will be considered, including:

- First scenario: Only Lean
- Second scenario: Only ERP
- Third scenario: Combined ERP-Lean.

The aim of this research is to see how ERP, Lean and ERP-Lean application affect the Backlog indicator. Due to Lean and ERP activities, the values of input parameters change which lead to the variation of Backlog. These values are considered based on the previous findings.

Historical data are collected and analyzed to determine the values of input parameters. However, only data for *Customer Order Rate* and *Rejection Fraction* can be found from historical documents of one year. Managers' interviews and observations are made to estimate the value for other variables. To simplify the reality and to make model feasible, the average number is used for these parameters. The results of these variables are presented in Table 1.

Table 1: Auxiliary variables of base case

Variable	Value	Unit
Customer Order Rate	6928	Units/ Day
Processing Time	7.11	Days
Target Delivery Delay	19.61	Days
Rejection Fraction	12.96	%
Material Safety Coverage	7	Days
Material Usage per Unit	1.2	N/A
Material Adjustment Time	7 (2 days of transaction)	Days
WIP Adjustment Time	4 (2 days of transaction)	Days
Delay Fraction	95.7	%

Since the role of ERP itself is to provide an information backbone to support the organization to control the material and information flows (Powell, Riezebos, et al., 2013), therefore, in this study, we assume that material-related activities improved only by Lean production, while transaction time-related activities can be adjusted by the ERP system.

As regards to the Lean application, the effects of Lean principles on manufacturing parameters in the textile industry are found in the literature review to have following improvements (Hodge, Goforth Ross, Joines, & Thoney, 2011):

- 30% in productivity (16% after one month)
- 50% in inventory
- 50% - 80% in quality (65% as average)

- 50% in lead time
- 50% in unnecessary set up time.

The effect of ERP on transaction time has not been addressed so far in the literature. Therefore, in case of ERP application, it is assumed with 25%, 50% and 75% improvement of the transaction time (of 2 days).

These percentages are used as predicted improvement percentages for manufacturing parameters when Lean and ERP are applied in future scenarios. Table 2 describes the future values.

Table 2: Input parameters of current state and future state

Variable	**Current state – Base case**	**Future scenarios**				
		Only Lean		**Only ERP**		**Combined**
		% improved	New value	% improved	New value	
Processing Time (Days)	7.11	30%	4.98	0%	7.11	4.98
Target Delivery Delay (Days)	19.61	50%	9.81	0%	19.61	9.81
Rejection Fraction (%)	12.96	65%	4.54	0%	12.96	4.54
Material Safety Coverage (Days)	7	50%	3.5	0%	7	3.5
Delay Fraction (%)	95.7	50%	97.85	0%	95.7	97.85
Material Usage per Unit	1.2	50%	1.1	0%	1.2	1.1
Material Adjustment Time (Days)	7	0%	7	25%, 50%, 75%	6.5 6 5.5	6.5 6 5.5
WIP Adjustment Time (Days)	4	0%	4	25%, 50%, 75%	3.5 3 2.5	3.5 3 2.5

4. Results and discussion

Since the data is collected for one year, the simulation is set for one year which is 269 working days. The simulation results of backlog and values of steady state of scenarios are presented in figure 3 and table 3.

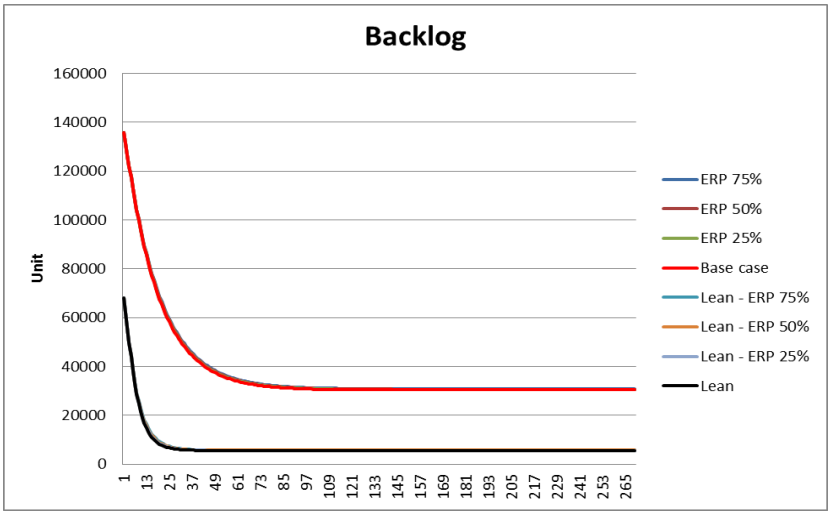

Figure 3: Backlog of scenarios

Table 3: Results of scenarios

Scenario	Steady value (units)
Base case	30380.1
ERP 25%	30532.1
ERP 50%	30689.1
ERP 75%	30863.1
Lean	5583.68
Lean - ERP 25%	5629.68
Lean - ERP 50%	5686.68
Lean - ERP 75%	5744.68

The results show that the system reaches the steady state after a number of replications (days). Historical data is used to validate the model. With the desired output of backlog, real data for this parameter is collected and compared with the simulation scenario of base case. The simulation result differs from the real data by only 3%. This means that the model structure yields meaningful behavior under the parameter values. For this reason, the model fairly accurately corresponds to the real-world system.

The most striking point is that Lean manufacturing dramatically improves the backlog issue for the manufacturing system. It can be clearly seen from figure 3 that in the Lean only scenario, the backlog can be improved up to 81.6% (from 30380.1 to 5583.68 units). On the other hand, improvements cannot be seen when ERP is implemented individually. The result shows a slight increase in the number of unfulfilled units with 0.5%, 1% and 1.5% respectively for 25%, 50% and 75% improvement in the ERP case. In the case of combined Lean and ERP application, the use of ERP does not bring any improvement for the manufacturing system comparing to the only Lean case.

Another striking point shown in figure 3 is the transition point. The manufacturing system reaches the steady state after around 20days in both case of Lean and combined, while it takes 60days in the current state and in ERP case.

The results are consistent with what is mentioned the literature about the role of Lean and ERP itself on the performance. Both practitioners and academics have confirmed the role of Lean in manufacturing generally and in the textile and apparel industry in particular. This simulation has also proved this point of view. The role of ERP has received doubts in practice and the simulation results also lend support to the view of objecting the role of ERP in the performance improvement. In both case of the manufacturing system, the application of ERP system does not cause positive effects for the system.

However, researchers claim that the failure of ERP is reported because of the gap between the actual business processes and the ERP system functions (Powell, Riezebos, et al., 2013). In practice, there are numerous cases where Lean practices have been successfully implemented thanks to the ERP system (Powell, Riezebos, et al., 2013). It is claimed that when Lean production practices facilitated by ERP, effective manufacturing systems is built with improved operational efficiency and reduced waste (Lenny Koh & Simpson, 2005; Powell, Alfnes, et al., 2013). And ERP can be developed to successfully support Lean production (Powell, Riezebos, et al., 2013).

Consequently, this research offers insights for the managerial implication of the role of the ERP system in Lean manufacturing. An ERP system should be designed to support Lean production with Lean features integrated into the software.

5. Conclusion

This paper has examined how the Lean and ERP system affect the manufacturing performance through a system dynamics approach. The textile and apparel industry was chosen as a case study and actual data was collected. The results highlight the role of Lean manufacturing itself and lend support to the view that ERP becomes a hindrance to Lean manufacturing when Lean practices are not properly integrated into the ERP system. Therefore, it is necessary for the companies to design an ERP-based Lean system and to build effective Lean practices before they can gain the benefits from the ERP system.

The ERP-enabled lean system is still new and requires further research for this application. In future, it is suggested to examine the effects of ERP-based Lean system on the manufacturing performance when ERP is built to support Lean system. In addition, building on the previous research of the maturity model of ERP support for pull production, the SD methodology can be used to further illustrate how the performance changes under different scenarios of the ERP-based Lean system. Also, future research could focus on extending the analysis to other sectors to see how ERP-based Lean system is adopted in a particular industry.

References

Bruun, P., & Mefford, R. N. (2004). Lean production and the Internet. *International journal of production economics*, *89*(3), 247-260.

Campuzano, F., & Mula, J. (2011). *Supply Chain Simulation: A System Dynamics Approach for Improving Performance*. London: Springer London: London.

Corinna Cagliano, A., DeMarco, A., Rafele, C., & Volpe, S. (2011). Using system dynamics in warehouse management: a fast-fashion case study. *Journal of Manufacturing Technology Management*, *22*(2), 171-188.

Ellram, L. M., Tate, W. L., & Carter, C. R. (2007). Product-process-supply chain: an integrative approach to three-dimensional concurrent engineering. *International Journal of Physical Distribution & Logistics Management*, *37*(4), 305-330.

Halgeri, P., McHaney, R., & Pei, Z. (2010). ERP systems supporting lean manufacturing in SMEs. *IGI Global*, Chapter 5.

Hodge, G. L., Goforth Ross, K., Joines, J. A., & Thoney, K. (2011). Adapting lean manufacturing principles to the textile industry. *Production Planning & Control*, *22*(3), 237-247.

Kanda, A., & Deshmukh, S. (2008). Supply chain coordination: perspectives, empirical studies and research directions. *International journal of production economics*, *115*(2), 316-335.

Laukkanen, S., Sarpola, S., & Hallikainen, P. (2007). Enterprise size matters: objectives and constraints of ERP adoption. *Journal of enterprise information management*, *20*(3), 319-334.

Lenny Koh, S., Saad, S., & Arunachalam, S. (2006). Competing in the 21st century supply chain through supply chain management and enterprise resource planning integration. *International Journal of Physical Distribution & Logistics Management*, *36*(6), 455-465.

Lenny Koh, S., & Simpson, M. (2005). Change and uncertainty in SME manufacturing environments using ERP. *Journal of Manufacturing Technology Management*, *16*(6), 629-653.

Pettersen, J. (2009). Defining lean production: some conceptual and practical issues. *The TQM Journal*, *21*(2), 127-142.

Poles, R. (2013). System Dynamics modelling of a production and inventory system for remanufacturing to evaluate system improvement strategies. *International Journal of Production Economics*, *144*(1), 189-199.

Powell, D., Alfnes, E., Strandhagen, J. O., & Dreyer, H. (2013). The concurrent application of lean production and ERP: Towards an ERP-based lean implementation process. *Computers in Industry*, *64*(3), 324-335.

Powell, D., Riezebos, J., & Strandhagen, J. O. (2013). Lean production and ERP systems in small-and medium-sized enterprises: ERP support for pull production. *International Journal of Production Research, 51*(2), 395-409.

Riezebos, J., Klingenberg, W., & Hicks, C. (2009). Lean Production and information technology: Connection or contradiction? *Computers in Industry, 60*(4), 237-247.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of operations management, 25*(4), 785-805.

Shtub, A., & Karni, R. (2010). *ERP: the dynamics of supply chain and process management*: Springer Science & Business Media.

Steger-Jensen, K., & Hvolby, H.-H. (2008). Review of an ERP system supporting lean manufacturing. *Lean Business Systems and Beyond*, 67-74.

Sterman, J. D. J. D. (2000). *Business dynamics: systems thinking and modeling for a complex world*: Irwin McGraw-Hii.

Ward, P., & Zhou, H. (2006). Impact of information technology integration and lean/just-in-time practices on lead-time performance. *Decision Sciences, 37*(2), 177-203.

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