Achieving Leanness: The relationship of Lean practices with process exploitation and exploration

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Abstract

Lean production is a socio-technical system allowing increasing operational effectiveness. It is widely assumed that Lean production contributes to the enhancement of operational efficiency through improvement of organizational processes and their interaction. However, the improvement could be achieved through processes of exploitation, exploration, or both. The survey of organizations adopting Lean production practices has shown that Lean production contributes to process control, incremental process improvement, and radical process improvement. The association of Lean production practices with radical process improvement constitutes the theoretical contribution of this article.

Keywords: Lean production, Process exploration, Process exploitation

Introduction

Lean production gained a reputation as robust set of practices allowing reducing waste and increasing operational efficiency (Womack et al., 1990; Shah and Ward, 2003; 2007). Variety of studies associated Lean practices with the improvement of multiple dimensions of performance. Empirical studies provided evidence that Lean practices are positively related with operational performance (Shah and Ward, 2003, 2007), financial performance (Hofer et al., 2012; Cua et al., 2001), environment performance (King and Lenox, 2001).

However, the nature of the improvement process which is facilitated by Lean practices is still under-researched phenomena. Improvement could be achieved through processes of exploitation, exploration, or both. Exploitation helps to achieve incremental improvement of organizational processes through tighter control and incremental improvement. Exploration enables to reinvent organizational processes, allowing achieving improved performance in a different way. In this article, we seek to shed a light in what extent the Lean practices contribute to process exploitation and process exploration.

Conceptual model

The predecessor of contemporary Lean production systems is just-in-time or Toyota production system (TPS) which was designed in the 1980s in Toyota (Schonberger, 2007). The worldwide adoption of TPS started in the 1990s when Womack et al. (1990) provided a compelling explanation of elements of TPS and suggested to use Lean as a synonym for the practices pioneered by Toyota (Hallgren and Olhager, 2009). Womack and Jones (1996) proposed five principles constituting Lean production: value stream, flow, pull, and perfection. These principles became guiding marks for organizations adopting Lean production.

Lean may be conceived as a manufacturing paradigm and as performance capability (Narasimhan et al., 2006). Lean as production paradigm is defined as „an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability“ (Shah and Ward, 2007 p. 791). The leanness of production as a performance capability is defined as if production "is accomplished with minimal waste due to unneeded operations, inefficient operations or excessive buffering" (Narasimhan et al., 2006, p.443). The organizations that adopted Lean production and achieved Leanness of its production enjoy increased productivity (Schmenner and Swink, 1997), superior cost effectiveness, high conformance quality of products (Narasimhan et al., 2006). Given these definitions, *a process of becoming Lean is a sequence of events enacted by a company to achieve Leanness of production.*

Variance and process models of Lean production are proposed to facilitate efforts of organizations to become Lean. Variance models explain phenomena through antecedents, constitutive concepts, and effects, process models – through a sequence of events (Langley, 1999). The variance model of Lean production, proposed by Shah and Ward (2003, 2007), is provided in Figure 1.

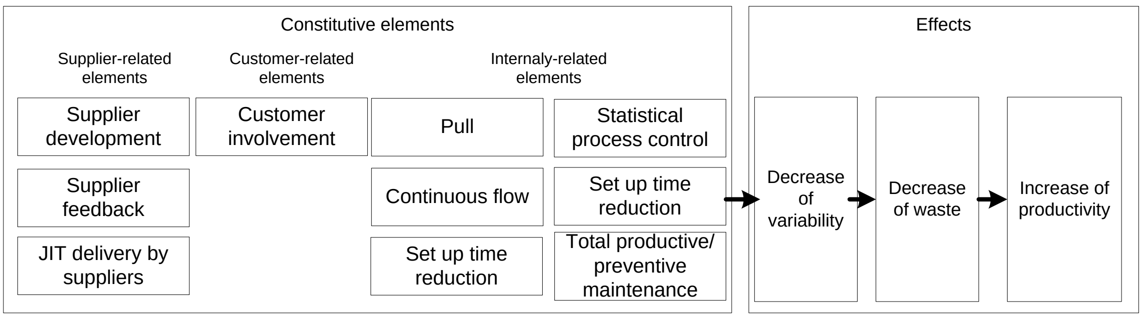

Figure 1 – Variance model of Len production

The ean production draws heavily on a concept of swift and even flow. The concept argues that "productivity of any process increases with the speed by which materials flow through the system, and it falls with increases with variability associated with the flow, be it variability of supply, demand or processing time" (Schmenner and Swink, 1997, p. 102). Accordingly, the objective of the Lean production is to "eliminate waste by reducing or minimizing variability related to supply, processing time and demand (Shah and Ward (2007). Ten supplier-related, customer-related and internally related elements reinforce each other to achieve the objective. Supplier-related and Customer-related elements help to explain the reduction of variability of supply and demand. The internally related elements explain how the variability of processing time is narrowed. The decrease of the variability of supply, demand and processing time allows reducing waste, such as overproduction, waiting time, transportation, unnecessary processing steps, raw materials inventory, and defects. Finally, the productivity of production system increase.

The conceptual model grounds the relationships of practices associated with Lean and types of process improvement. Definition of Lean is consistent with Shah and Ward (2007).

Following Ng et al (2015) is proposed that exploitation constitutes efforts to control processes and improve them incrementally. Exploration constitutes a radical improvement of production processes. The definitions of process control, incremental and radical process improvement are consistent with Ng et al. (2015).

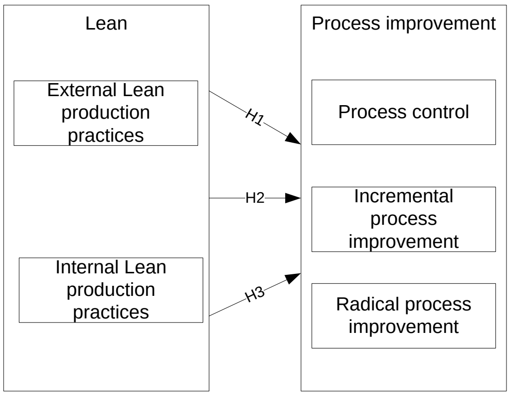

Figure 2 – The relationship between Lean production and types of process improvement

Positive relationships between Lean practices and types of improvement are hypothesized drawing from the perspective of a duality of exploration and exploitation.

Methods

Firm-level data from organizations which have exposure to lean methods were collected using internet-based survey. The sampling frame was constructed using information provided by Association of Lean Professionals of Lithuania and other data. The email asking to fill in the Internet-based questionnaire from Association of Lean Professionals was sent to the companies. In total 75 responses were obtained.

Variety of measures addressing characteristics of companies, a manifestation of Lean practices and process improvement were employed. Process control, incremental and radical improvement was measured using items suggested by Ng et al. (2015). 14 statements were provided for respondents who were asked to express their agreement to the statements on 5 point Likert scale. Exploratory factor analysis (EFA) was used to evaluate unidimensionality of constructs (extraction method: principal component analysis; Rotation method: Varimax with Kaiser normalization; cases excluded listwise, valid cases N = 71). Measurement of internal consistency reliability provided satisfactory results (Cronbach's $\alpha > 0{,}7$ for all scales).

After reviewing different ways of measurement of Lean production (Shah and Ward, 2003; 2007; Hallgren and Olhager, 2009; Fullerton et al, 2008), Shah and Ward's (2003) framework was used as a guiding framework. Methods constituting each of four groups of practices was listed and companies were asked to evaluate their usage using 5 points Likert scale. The methods loaded into 6 groups during EFA (extraction method: Principal component analysis; Rotation method: Varimax with Kaiser normalization;

missing values were replaced by means). Internal consistency of all scales was validated (Cronbach's α > 0,7 in all cases).

Correlations between types of process improvement and bundles of Lean practices were calculated. Multiple linear regression was conducted to measure the impact of bundles of Lean practices on types of process improvement. Cases were excluded listwise, valid number of cases N = 71. F-tests confirmed the linearity of the emerged models (p = 0,000 for incremental process improvement, p = 0,016/0,011/0,000 for process control, p = 0,001 for radical process improvement). The fulfillment of the assumption of independence of errors was verified by means of Durbin-Watson statistic (2,011 for incremental process improvement, 1,378/1,391/1,693 for process control, and 1,842 for radical process improvement). To test homoscedasticity of the errors, plots of standardized residuals versus standardized predicted values were produced. The same plots served for the identification of outliers; they were absent (all residuals < |3,5|). To confirm the normality of the error distribution, normal probability plots of the residuals were produced. In addition, Shapiro-Wilk test did not reject the normality of residual distribution (p = 0,512 for incremental process improvement, p = 0,969/0,724/0,442 for process control, p = 0,485 for radical process improvement). Variance inflation factor and condition index were estimated to reject collinearity.

Results

Types of process improvement

The items measuring process control, incremental and radical improvement loaded into three factors as expected. The rotation converged in 5 iterations. Kaiser-Meyer-Olkin measures of sampling adequacy (KMO MSA) exceed 0,7 and indicate that the observed variables are suitable for EFA. Bartlett's test of sphericity rejects the hypothesis about non-correlation of the variables (p = 0,000). Cronbach's α values are above 0,7 and confirm the good internal consistency of the variables within each component. The factor solution is presented in Table 1.

Table 1 – Types of process improvement

Items measuring process improvement	Factor loadings (L)			Factor entitlements	Cronbach's alpha	Mean
We implement process improvement in a gradual way	0,813	0,182	0,139			
We seek ways to simplify existing processes	0,811	0,150	0,112			
We encourage front-line employees to participate in process improvement teams	0,793	0,189	0,139			
Our senior management encourages "thinking out of the box"	0,697	0,046	0,276			
We run process improvement projects on a continual basis	0,694	0,355	0,239			
We continuously reduce process variation, even if process variation is already at an acceptable level	0,652	0,345	0,205			
We provide adequate task-related training to front-line workers	0,470	0,257	0,464			

We have well-established methods to measure and analyze the quality of our products and services	0,166	0,830	0,023			
We have site-wide, standardized, and documented operating procedures	0,097	0,754	0,185	Process control	0,828	4,063
We perform housekeeping to ensure that the plant is neat and tidy	0,255	0,697	0,165			
Most of our core processes have a clear and measurable performance indicator	0,433	0,637	0,022			
We implement radical and newly designed processes	0,204	0,201	0,876			
We design and implement a totally new process	0,451	-0,111	0,766			
We use IT as an enabler in process redesign	0,031	0,491	0,580			

The factor solution explains 65,258% of the total variance, where the factors account for 29,246%, 20,338% and 15,673% of the variance accordingly, thus meaning that incremental process improvements prevail. Respectively, the mean value of this factor equals 4,123, followed by process control (mean = 4,063) and radical process improvement (mean = 3,698). Figure 3 demonstrates the distribution of the sample companies along the three dimensions of process improvement.

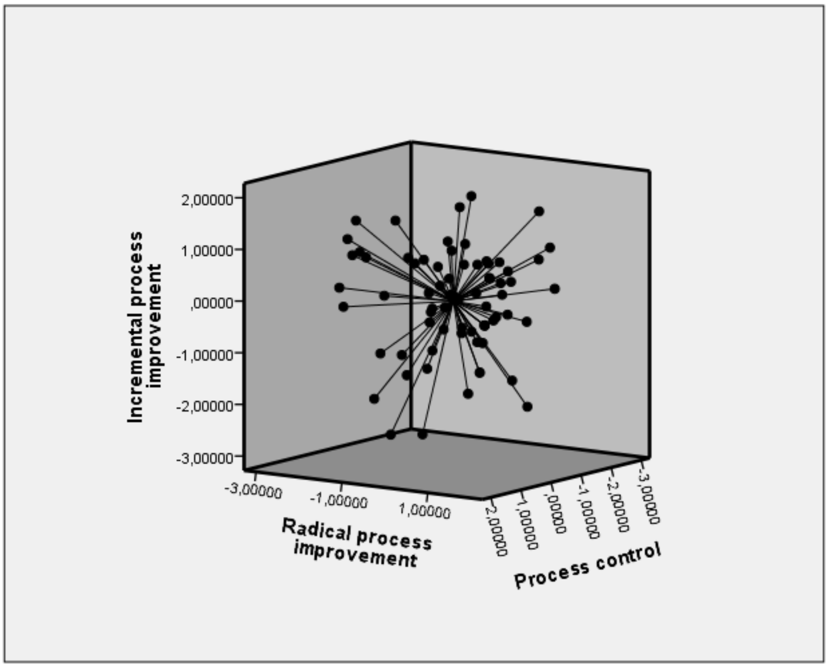

Figure 3 – Sample companies across the types of process improvement

As many as 34,742% of the sample companies do not follow the computed solution and improve processes by mixed means, yet inclined to incremental changes and process control procedures more than to radical changes. Hence, a considerable number of markers are much centered in figure 2 and indicate that the sample organizations seldom demonstrate unambiguous patterns of process improvement.

Interestingly, according to Ng's et al. (2015) scale, two items of the first computed component relate to other types of process improvement and are typed in italics in Table 1. 'Thinking out of the box' is traditionally associated with radical process improvement, while in the Lithuanian sample less radical changes seem to require more creativity from employees (L = 0,697) than when dealing with totally new processes (L = 0,276). Task-related training to front-line workers relates to process control (Ng et al., 2015), but it is generally common to provide adequate training to front-line workers in Lithuania, so this item is almost equally split between incremental and radical process improvements (L = 0,470 and L = 0,464 accordingly) and is more rarely associated with routine process control (L = 0,257). Other than that, the factors of process control and radical process improvement encompass items which conventionally fall under the same types of process improvement as in Ng's et al. (2015) study.

Bundles of Lean practices

The Lean practices loaded into 6 factors (KMO MSA = 0,837; Bartlett's test's of sphericity p = 0,000) as demonstrated in Table 2. The rotation converged in 9 iterations.

Table 2 – Bundles of Lean practices

Lean practices	**Factor loadings (L)**						**Factor entitlements**	**Cronbach's alpha**	**Mean**
Lean boards	0,812	0,093	0,046	0,117	0,064	0,125			
A3	0,705	0,309	-0,056	-0,014	-0,131	0,059			
Kaizen teams	0,666	0,131	0,101	0,253	0,101	0,041			
Gemba	0,666	0,095	0,136	0,285	0,215	0,021			
Competences matrix	0,620	0,183	0,244	0,108	0,125	0,303			
Indicator cascading and problem escalation chain	0,614	0,052	-0,026	0,221	0,441	0,135			
Takt time	0,156	0,702	0,406	-0,089	0,219	-0,082			
One piece flow	-0,089	0,653	0,536	-0,029	-0,065	0,074			
Just In Time production (services)	0,032	0,648	0,150	0,432	0,331	0,158			
Work standartisation	0,471	0,646	-0,022	0,214	0,253	-0,032			
Leveled production	0,288	0,637	0,447	-0,044	0,175	0,181			
Kanban, standartised internal logistics	0,320	0,612	0,215	0,315	0,013	0,084			
Integration of quality into work processes	0,264	0,586	0,006	0,176	0,352	0,155			
Just In Time purchasing	0,223	0,564	-0,054	0,269	0,460	0,269			
U line	0,093	0,141	0,877	0,188	0,144	0,006			
Integrated line	0,116	0,128	0,854	0,199	0,268	-0,019			
Processing cell	0,070	0,165	0,798	0,245	0,106	0,078			
Involvement of suppliers and customers into improvement	0,067	0,166	0,210	0,724	0,082	0,230			

5 Why	0,344	0,170	0,221	0,695	0,059	0,099			
Cause-efect diagram	0,349	0,224	0,196	0,652	-0,042	0,231			
Deming cycle (PDCA)	0,393	-0,105	0,088	0,604	0,243	0,109			
Single minute exchange of die	0,142	0,183	0,194	0,142	0,793	0,054			
Overall equipment effectiveness	0,205	0,325	0,268	-0,224	0,723	0,104			
Autonomous maintenance of equipment	-0,013	0,239	0,265	0,328	0,642	0,255			
Flow diagram	0,087	-0,037	0,000	0,088	0,254	0,861			
Process map	0,086	0,029	0,041	0,193	0,070	0,839			
Process owners	0,173	0,375	-0,083	0,261	0,118	0,607			
Value stream mapping	0,381	0,242	0,338	0,071	-0,231	0,548			

The factor solution explains 70,234% of the total variance, where the first two factors, i.e., the involvement of employees and pull production, account for the highest proportions: 14,444% and 14,084% respectively. Their means are also the greatest out of the six components, even though the use of Lean practices associated with the factors mentioned above falls mostly between 'sometimes' and 'often' (mean = 3,548 for the involvement of employees and mean = 3,400 for pull production).

Continuous flow explains 12,128% of the total variance. However, its mean = 1,952 indicates that most organizations seldom or never use such Lean practices as U line, integrated line, and processing cell.

10,341% of the sample binds together practices that are related to the involvement of suppliers and customers into process improvement. It is common to mostly sometimes (mean = 3,201) use such Lean practices as Cause-effect diagram, 5 Why or Deming cycle.

The bundle of SMED, OEE, and autonomous maintenance can be referred to as equipment maintenance and setup time reduction and accounts for 9,831% of the total variance. It is another bundle of Lean practices which is not that common to use: the factor's mean equals 2,661 and falls between 'rarely' and 'sometimes'.

A similar proportion of the variance (9,404%) is represented by Lean practices which can be referred to as process value stream analysis. The usage of these practices is moderate (mean = 3,219) among the sample organizations.

Relationships between Lean practices and types of process improvement

Correlations indicate mostly positive relationships between groups of Lean practices and types of process improvement (see Table 3). All the negative relationships are weak or close to non-existent, and they are not statistically significant.

Table 3 – Relationships between Lean practices and types of process improvement

Types of process improvement / Bundles of Lean practices	**Involvement of employees**	**Pull production**	**Continuous flow**	**Involvement of suppliers and customers**	**Equipment maintenance and setup time reduction**	**Process value stream analysis**

Incremental process improvement	Pearson r	0,515**	0,152	-0,015	0,339**	0,038	-0,033
	Sig.	0,000	0,204	0,902	0,004	0,750	0,786
	Spearman rho	0,527**	0,076	-0,038	0,362**	0,056	0,036
	Sig.	0,000	0,530	0,754	0,002	0,644	0,767
	Pearson r	0,098	0,284*	-0,011	0,109	0,216	0,189
	Sig.	0,417	0,016	0,929	0,364	0,070	0,115
	Spearman rho	0,139	0,298*	-0,027	0,184	0,199	0,175
	Sig.	0,247	0,012	0,821	0,125	0,096	0,145
	Pearson r	0,082	-0,048	0,086	0,397**	0,068	-0,151
	Sig.	0,498	0,693	0,474	0,001	0,572	0,209
	Spearman rho	0,108	-0,113	0,071	0,292*	0,015	-0,118
	Sig.	0,371	0,350	0,555	0,013	0,898	0,326
* p ≤ 0.05; ** p ≤ 0.01							

Involvement of employees and to a lesser extent – suppliers and customers are positively associated with incremental process improvement. Process control is most positively related to pull production, even though the correlation is weak. A bit stronger positive, yet weak relationship binds together radical process improvement and involvement of suppliers and customers.

According to Table 3, statistically significant monotonous correlations are slightly stronger than the linear ones. However, the linear correlation between radical process improvement and involvement of suppliers and customers is considerably stronger than the monotonous one. So, the model of linear regression seems to be appropriate to indicate the impact of Lean practices on types of process improvement.

Impact of bundles of Lean practices on types of process improvement

According to the most appropriate regression model, incremental process improvement depends on the involvement of employees and involvement of suppliers and customers as indicated by equation (1):

$$IPI = 0{,}504\ IoE + 0{,}321\ IoSC, \qquad (1)$$

here *IPI* – incremental process improvement,
IoE – involvement of employees (p = 0,000),
IoSC – involvement of suppliers and customers (p = 0,001).

In (1), the adjusted coefficient of determination indicates a reserved fit of the model (R^2_{adj} = 0,350), the standard error of the estimate σ_{est} = 0,806. Hence, the data are scattered around the linear model, but the linearity was confirmed (F-test p = 0,000).

Originally, a single regression model was computed to measure the dependence of process control on Lean practices (2):

$$PC = 0{,}284\ PP, \qquad (2)$$

here *PC* – process control,
PP – pull production (p = 0,016).

However, the bundle referred to as equipment maintenance and setup time reduction was rejected with p = 0,069, and the increase of entry barrier up to 0,07 slightly improves the model (F-test p = 0,016, R^2_{adj} = 0,068, σ_{est} = 0,966, DW = 1,378 vs. F-test p = 0,011, R^2_{adj} = 0,099, σ_{est} = 0,949, DW = 1,391). So, equation (3) better represents the impact of Lean practices on process control despite its poorer predictive value against equation (2).

$$PC = 0{,}284\ PP + 0{,}210\ EMaSTR, \quad (3)$$

here *PC* – process control,
PP – pull production (p = 0,016),
EMaSTR – equipment maintenance and setup time reduction (p = 0,069).

The elimination of cases with the most negative scores (<-1) on pull production significantly improves the regression model (from F-test p = 0,016, R^2_{adj} = 0,068, σ_{est} = 0,966, DW = 1,378 to F-test p = 0,000, R^2_{adj} = 0,340, σ_{est} = 0,816, DW = 1,693), still leaving the number of valid cases satisfactory (N = 61). Equation (4) describes the updated regression model:

$$PC = 0{,}504\ PP + 0{,}298\ EMaSTR + 0{,}253\ IoE + 0{,}235\ PVSA + 0{,}229\ IoSC,$$

here PC – process control,
PP – pull production (p = 0,000),
EMaSTR – equipment maintenance and setup time reduction (p = 0,007),
IoE – involvement of employees (p = 0,020),
PVSA – process value stream analysis (p = 0,030),
IoSC – involvement of suppliers and customers (p = 0,037).

The dependence of radical process improvement on Lean practices is described by equation (5):

$$RPI = 0{,}397\ IoSC, \quad (5)$$

here *RPI* – radical process improvement,
IoSC – involvement of suppliers and customers (p = 0,001).

In (5), the adjusted coefficient of determination indicates a very reserved fit of the model (R^2_{adj} = 0,145), the standard error of the estimate σ_{est} = 0,924. So, the data are broadly scattered around the linear model, but its linearity was confirmed (F-test p = 0,001).

Conclusions

Lean production is a socio-technical system allowing increasing operational effectiveness. It is widely assumed that Lean production contributes to an improvement of operational efficiency through improvement of organizational processes and their coherence. However, the improvement could be achieved through processes of exploitation, exploration, or both. Exploitation helps to achieve incremental improvement of organizational processes through tighter control and incremental improvement. Exploration enables to reinvent organizational processes, allowing achieving improved performance in a different way.

The survey of organizations adopting Lean production practices has shown that Lean production contributes to process control, incremental process improvement, and radical process improvement. Practices related to Pull production and Equipment maintenance and setup time reduction contribute to process control activities. Practices related to Involvement of employees and Involvement of suppliers and customers into improvement contribute to the Incremental improvement of organizational processes. Finally, practices related to Involvement of suppliers and customers contribute to the radical improvement of organizational processes.

This research contributes to Lean production research by associating Lean production practices, particularly Involvement of suppliers and customers in radical process improvement.

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