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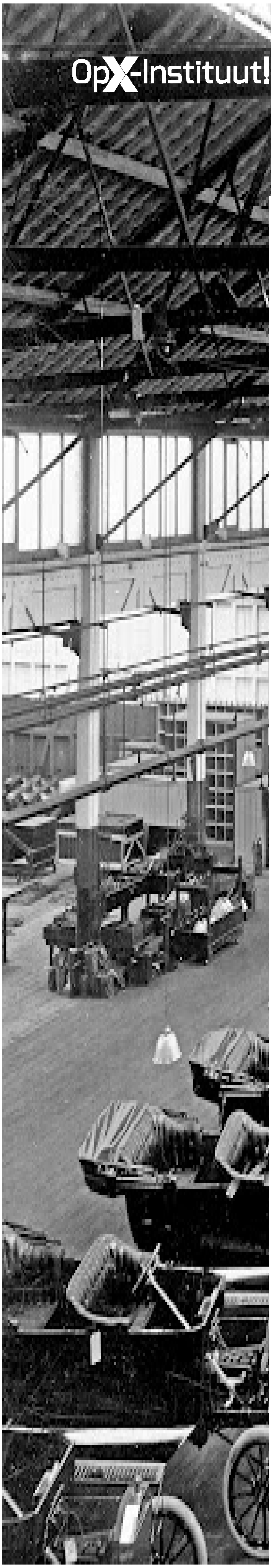
Lean practices, Lean tools & performance

Research paper

Lean is often considered as a collection of tools and practices that can be used to achieve superior operational and financial performance by means of process improvements. This research examines this proposition. Survey data of 199 responses from Dutch organizations, shows that Lean practices directly impact process improvement performance and indirectly impacts financial performance. However, this study also shows that this relationship is affected by the type of market. The impact of Lean practices on process improvement performance is enhanced in a commodity market in which standardization is important, but weakened in a capability market in which customer effectiveness is perceived to be important.



CONTENT

Lean is often considered as a collection of tools and practices that can be used to achieve superior operational and financial performance by means of process improvements. It is unclear, however, how the use of operational Lean tools is related to Lean practices that constitute a Lean infrastructure of sorts, or what the impact of both Lean measures is on process improvement and ultimately on customer performance and financial performance. Survey data of 199 responses from Dutch organizations, shows that Lean practices directly impact process improvement performance and indirectly impacts financial performance. However, this study also shows that this relationship is affected by the type of market. The impact of Lean practices on process improvement performance is enhanced in a commodity market in which standardization is important, but weakened in a capability market in which customer effectiveness is perceived to be important. In this study, we distinguish between Lean practices that constitute infrastructural Lean capabilities and the use of operational Lean tools. Of course, Lean practices and the use of Lean tools are closely related, but this study shows that the use of Lean tools does not directly impact process improvement performance or customer effectiveness performance, never mind financial performance. This study shows that the variable, Lean practices, is a mediating factor in the relationship between the use of Lean tools and process improvement performance. In other words, to be effective, the use of Lean tools must be embedded in a bundle of infrastructural Lean practices.

1. INTRODUCTION

Lean is a popular concept for improving operational performance in production environments (Cua, McKone & Schroeder, 2001; Shah & Ward, 2003) and service environments (Swank, 2003; LaGanga, 2011; Meredith et al., 2011). Lean manufacturing is defined as a collection of practices that work together synergistically to create a high quality, streamlined system that produces finished products with little or no waste at the rate of customer demand (Shah & Ward, 2003). Practices commonly associated with Lean manufacturing include the capability to create flow including set-up time reduction and pull control (Cua et al., 2001; Cagliano, Caniato & Spina, 2006), quality control (Flynn, Sakakibara & Schroeder, 1995; Samson & Terziovski, 1999; Narasimhan, Swink & Kim, 2006) and human resource development (Sakakibara, Flynn, Schroeder & Morris, 1997; Ichniowski & Shaw 1997), ultimately to improve firm performance (Fullerton & McWatters, 2001; Eroglu & Hofer, 2010). However, some studies found that Lean/JIT has a positive impact on financial performance (Claycomb, Germain & Dröge, 1999; Fullerton, McWatters & Fawson, 2003) while others found no impact (Balakrishnan, Linsmeier & Venkatachalam, 1996; Jayaram, Vickery & Dröge, 2008). This inconsistency is explained by pointing out that Lean directly impacts operational performance and indirectly impacts financial performance (Nair, 2006; Mackelprang & Nair, 2010) and that there are various other mediating factors in the relationship between Lean and financial performance, including the use of non-financial performance measures (Fullerton & Wempe, 2009), environmental complexity and dynamism (Azadegan, Patel, Zangoueinezhad & Linderman, 2013) and the building of close relationships with key supply chain partners (Jayaram et al., 2008).

Another explanation is found in the operational definitions used (Davies & Kochhar, 2002; Mackelprang & Nair, 2010). For instance, Azadegan et al. (2013) found that not all Lean practices are suitable in any environment, while Mackelprang & Nair (2010) warned that the current operational definitions are more suitable for production environments and less

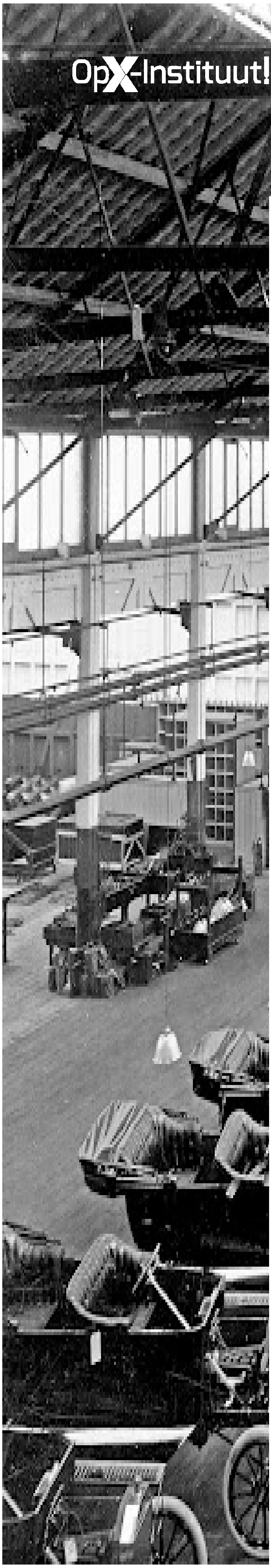
for service environments. Researchers operationally defined Lean as the use of operational Lean tools (Karlsson & Åhlström, 1996; Sanchez & Perez, 2001), as a set of individual Lean practices (Shah & Ward, 2003; Shah, Chandrasekaran & Linderman, 2008) or as a bundle of tactical Lean practices or capabilities that constitute a type of a Lean infrastructure (Narasimhan et al., 2006; Shah & Ward, 2007; Anand, Ward, Tatikonda & Schilling, 2009). Typical operational tools are Kano-analysis (Lin, Yang, Chan & Sheu, 2010) and value stream mapping (Tyagi., Choudhary, Cai & Yang, 2015), while JIT (Green, Inman, Birou & Whitten, 2014) and continuous improvement (Anand et al., 2009) are more institutionalized practices or capabilities (Cepeda & Vera, 2007; Peng, Schroeder & Shah, 2008). However, Lean practices are generally lumped together which impedes a full understanding of Lean since particularly the interrelationships between the use of operational Lean tools, Lean routines or capabilities and Lean Leadership determine the effectiveness of Lean (Spear & Bowen, 1999; Takeuchi, Osono & Shimizu, 2008). This concurs with the finding of Mackelprang & Nair (2010) that not only the interrelationship of Lean/JIT practices has to be examined but also the indirect effects of Lean/JIT practices on performance, and in particular the interaction effects between tools and infrastructural practices or capabilities. To the best of our knowledge, there is little empirical research on the relationship between the use of various operational Lean tools and infrastructural Lean practices. This seems to be a shortcoming as most Lean implementation programs consist of the structured training and use of operational Lean tools on the one hand (Dale & McQuater, 1998; Feld, 2000; Pavnaskar, Gershenson & Jambekar, 2003) and managerial and infrastructural practices on the other hand (Peng et al., 2008; Netland, Schloetzer & Ferdows, 2015) that may constitute cumulative (Flynn & Flynn, 2004) or even dynamic capabilities (Anand et al., 2009). Also the impact of the use of operational Lean tools on operational performance and subsequently on customer and financial performance is underexposed in the academic literature.

This paper, contributes to the existing literature on Lean by examining the relationship between the use of operational Lean tools and other Lean practices (i.e. infrastructural Lean capabilities) and the impact of both Lean practices and the use of operational Lean tools on process improvement performance and subsequently on customer performance and financial performance. In addition, this study takes into account the type of market as a mediating variable, i.e. the perceived importance of standardization in the market (as a proxy for the level of commoditization in the market) and the perceived importance of customer effectiveness in the market (as a proxy for the level of differentiation in the market).

This paper is organized as follows: section 2 presents the research model with hypotheses. Data, variables and research methods to validate the research model are discussed in section 3 and the statistical results are described in section 4. The findings and the implications for practice and (future) research are discussed in section 5.

2. LITERATURE REVIEW AND RESEARCH MODEL

Though the term Lean was introduced by Krafcik (1988), it became globally renowned after the book ‘The machine that changed the world’ by Womack, Jones & Roos was published in 1990. After that, Lean became related to superior productivity and quality, supposedly due to the use of various Lean tools and practices (Oliver, Delbridge, Jones & Lowe, 1994). In their quest to operationalize Lean by means of individual Lean tools, practices and principles, Karlsson & Åhlström (1996) and Shah & Ward (2003) adopted this view, although numerous researchers had already empirically measured Just-In-Time (Sakakibara et al., 1997; McLachlin, 1997), Total Quality Management (Dean & Bowen, 1994; Sitkin, Sutcliffe & Schroeder, 1994) or a combination of JIT and TQM (Flynn et al., 1995) by means of related practices. Since then various articles and as many measures of Lean have appeared; these range from operationalizations comprising individual tools



measured by single items only (Sanchez & Perez, 2001; Ahmed & Hassan, 2003; Tari & Sabater, 2004) or measured by single items and then categorized using factor analysis (Sila & Ebrahimpour, 2003; Shah et al., 2008) to tactical or infrastructural practices measured by multiple-items (Narasimhan et al., 2006; de Treville & Antonakis, 2006; Shah & Ward, 2007). Mackelprang & Nair (2010) also stated that "various studies have captured individual JIT practices by widely varying means, ranging from using multi-item validated scales to capture individual JIT practices to using a single variable to capture all of JIT and as a consequence that the understanding of what actually comprises JIT or Lean becomes blurred from study to study". Hines, Holweg & Rich (2004) made a clear distinction between the Lean production system, i.e. the application of (operational) tools designed for the development/management of the production area, and the application of Lean thinking as a tactical or even a strategic approach.

Current state value stream mapping and Pareto charts are operational Lean tools (Rivera & Chen, 2007; Belekoukias, Garza-Reyes & Kumar, 2014; Tyagi et al., 2015) to describe and map a process and evaluate process waste, while a RACI model is used to relate a process description with the tasks, authorities and responsibilities of specific roles in an organization (Feld, 2000). These operational tools are typically used as part of process management. Process management on the other hand is again contextualized as one element of a broader framework such as the EFQM Excellence model (Flynn & Saladin, 2001; Wilson & Collier, 2000) and as a Lean practice (Fullerton & Wempe, 2009; Zhang, Linderman & Schroeder, 2012). In a similar vein, we argue that the use of Kanban cards to trigger production and material replenishment (Schonberger, 1983) and the use of bins in a two-bin system (Landry & Beaulieu, 2010) are operational tools used within a pull control capability. Jidoka and the use of poke-yoke devices (MacDuffie, 1997) are operational instruments and tools within an organization's quality management capability, while TQM is an infrastructural practice, or even a philosophy, described by Shah & Ward (2007) as one of the Lean bundles.

Operational Lean tools can be classified according the five principles of Lean (Womack & Jones, 2003), also known as the VVFPP-model: (1) Value: specify value in terms of the customer; (2) Value chain: map the value stream – and eliminate non-value-added tasks; (3) Flow: create continuous, single-piece flow wherever possible; (4) Pull: only flow a product when a customer pulls it; and (5) Perfection: seek perfection through continuous improvement; see Table 1. We therefore distinguish i) customer value tools to evaluate what customers value, need and desire, ii) process mapping and root-cause analysis tools (RCT) to map and evaluate processes and analyze for improvements, iii) visual management tools (VMT) to communicate through visual signals instead of text or written instructions, iv) pull control tools (PCT) to control the flow of work by only releasing materials onto the work floor as the customer demands them, i.e. only when they are needed, and v) Kaizen improvement tools (KIT) to facilitate continuous improvement (Browning & Heath, 2009; Lin et al., 2010; Tyagi et al., 2015). Visual management tools, for instance, are intended to make processes as simple as possible, resulting in higher process improvement performance (Pavnaskar et al., 2003). Good housekeeping tools such as 5S are intended to develop productive standardized workplaces to reduce waste, increase efficiency and as a result decrease waiting times (Rivera & Chen, 2007)

The use of operational Lean tools is a minimum, but not sufficient condition for the development of Lean practices as a Lean infrastructure (e.g., Anand et al., 2009) for which a culture of continuous improvement (Choi & Liker, 1995) and Lean leadership (McLachlin, 1997; Sosik & Dionne, 1997) are also necessary. We presume that Lean practices are built through the use of operational Lean tools amongst others. We therefore have the following hypothesis:

H1. The use of Lean tools is positively related to Lean practices

Lean practices, both infrastructural capabilities and operational tools, are all geared towards the increase of operational efficiency (Samson & Terziovski, 1999; Gustafsson & Nilsson, 2003) by the reduction of waste i.e. scrap and rework costs (Shah & Ward, 2003) and the elimination of dysfunctional variability (Hopp & Spearman, 2004; de Treville & Antonakis, 2006). Lean practices positively relate to process improvement performance (Cua et al., 2001; Shah et al., 2008). Various bundles of operational tools such as root-cause analysis tools, visual management tools, pull control tools and Kaizen improvement tools are aimed at reducing waste, complexity and variability through the improvement of processes (Choi & Eboch, 1998; Sila, 2007; Gligor, Esmark & Holcomb, 2015; Davies & Kochhar, 2002). The higher the degree of implementation of Lean practices and operational tools, the better the operational performance (Thun, Druke & Grubner, 2010). We therefore hypothesize that both the use of operational Lean tools and infrastructural Lean practices lead to higher process improvement performance.

H2. Lean practices are positively related to process improvement performance
H3. The use of Lean tools is positively related to process improvement performance

The most commonly cited benefits in relation to Lean practices are improvement in labor productivity and quality, along with reduction in customer lead time (White, Pearson & Wilson, 1999; Shah & Ward, 2003). Indeed, the ultimate purpose of Lean practices is the continuous improvement of work processes for the purpose of customer value (Hines et al., 2004). A survey study of Coyle-Shapiro (2002) supports the notion that continuous improvement is a core factor for TQM, and results in higher customer satisfaction. TQM practices have a stronger impact on customer satisfaction than on plant performance (Choi & Eboch, 1998). Time-based manufacturing practices (i.e., Just-In-Time) positively impact the value to customer (Tu, Vonderembse & Nathan, 2001) through internal process improvement and greater customer focus (Done, Voss & Rytter, 2011). Since TQM and time-based manufacturing practices are included in the operational definition of Lean practices, we hypothesize that both Lean infrastructural practices and the use of Lean tools are positively related to customer response performance.

H4. Lean practices are positively related to customer response performance
H5. The use of Lean tools is positively related to customer response performance

Process improvements (i.e. reduction of waste and complexity) result in higher delivery reliability, shorter lead times and thus quicker response to demand, hence better customer response performance. Process improvement positively impacts performance (Ahire & Dreyfus, 2000), though it has a greater effect on customer performance than on financial results (Wilson & Collier, 2000). Anderson, Jerman & Crum (1998) also reported a positive effect of operational performance on customer results. We therefore hypothesize that process improvement performance is positively related to customer response performance.

H6. Process improvement performance is positively related to customer response performance

Fullerton et al. (2003) found that the degree of specific JIT practices used, waste-reducing production practices in particular, positively impacts financial performance. A Lean management philosophy of waste elimination and continuous improvement leads to more efficient operations, less rework costs and less inventory costs (Fullerton & Wempe, 2009). Hence, Lean directly impacts operational performance and indirectly impacts financial performance (Mackelprang & Nair, 2010). Process improvement performance is a mediating construct in the relationship between Lean and financial performance (Samson & Terziovski, 1999; Belekoukias et al., 2014). We therefore hypothesize that process improvement positively impacts financial performance.

H7. Process improvement performance is positively related to financial performance

Higher operational delivery performance (i.e. customer response performance) results in higher customer satisfaction (Anderson et al., 1998; Sila, 2007). Kumar, Batista & Maull (2011) reported a relationship between customer response performance (i.e. higher the delivery dependability and quality) and customer satisfaction. We therefore hypothesize the following:

H8. Customer response performance is positively related to customer satisfaction

Empirical studies that test the service-profit chain (Heskett, Jones, Loveman, Sasser & Schlesinger, 1994) reported a positive relationship between customer satisfaction and financial performance (Gustafsson & Johnson, 2002; Wright & Snell, 2002). The general argument is that customer satisfaction creates customer loyalty and retention, resulting in repeat purchases, growth in sales, a reduction in operating costs, and an increase in profits (Anderson, Fornell & Lehman, 1994; Das, Handfield, Calantone & Ghosh, 2000; Bernhardt, Donthu & Kennett, 2000; Yeung & Ennew, 2001). We therefore hypothesize the following:

H9. Customer satisfaction is positively related to financial performance

Azadegan et al. (2013) found that environmental complexity positively moderates the performance effects, and that environmental dynamism reduces the performance benefits, of Lean operations. This concurs with the general assumption that Lean is particularly appropriate in stable, repetitive environments in which standardization is important (Hopp & Spearman, 2004). Lean is also associated with the commoditization of processes (Davenport, 2005). In contrast, agility is assumed to be more appropriate in dynamic and uncertain markets (i.e. capability markets with a high level of differentiation) which satisfy a fluctuating demand through quick response, while Lean manufacturing requires a level scheduling (Naylor, Naim & Berry, 1999). We can therefore also hypothesize the following:

H10. The impact of Lean practices on performance is positively moderated by the level of commoditization in the market and negatively moderated by the level of differentiation.
H11. The impact of the use of Lean tools on performance is positively moderated by the level of commoditization and negatively moderated by the level of differentiation in the market.

In summary our theoretical model of the impact of Lean variables on performance is illustrated in figure 1.

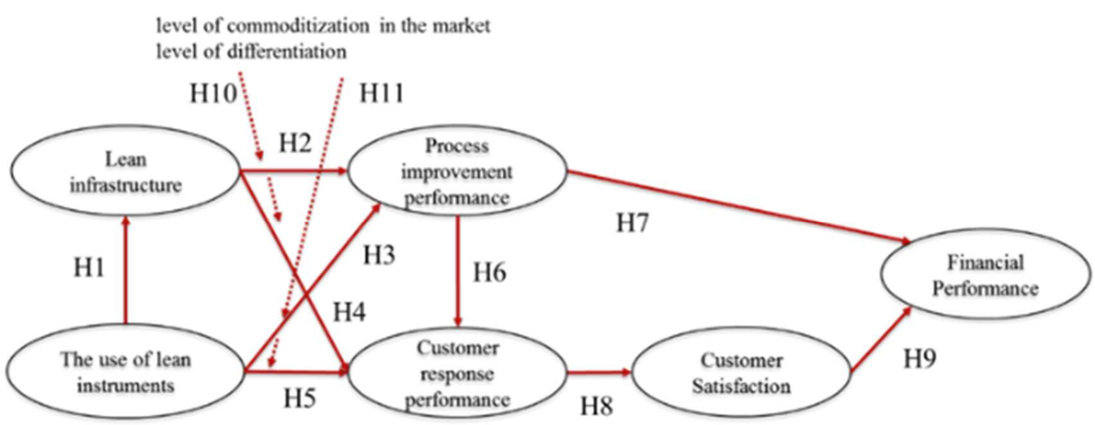


Figure 1. Hypothesized research model.

3. METHODOLOGY

3.1. Data collection

We used data collected from business school participants in the period 2012/2013 to test the hypothesized research model. Participants were predominantly middle managers. We employed a web-based survey approach, which participants filled out before they attended an Operational Excellence / Lean related course. We explicitly remarked that we would use the results anonymously as a type of OpX-scan during the course. 80% of the participants filled out the questionnaire resulting in 205 questionnaires, of which 199 were useful for research. About 10% of the respondents had a higher management position, 66% of the respondents were middle-managers, the remaining respondents had no management position but had job titles equivalent to internal advisors, logistics engineer and operations controller. The respondents averaged 8.5 years' work experience with their current organization: see Table 2. Non-response bias was evaluated by testing responses of 21 non-informants for significant differences during the courses (Mentzer & Flint, 1997), where they were asked to respond verbally to five substantive items related to key constructs of the whole survey. There were no significant differences ($p < .05$) in responses to any item, leading to the conclusion that non-response bias was not a problem.

NAICS codes	Type of industry	%	Function	Percentage	Years of employment at this organization	%
22	Energy	5	Non-management	23,6	<1 year	5
23	Construction	2	Middle-management	66,3	1-3 years	12
31 - 33	Industry	17	Higher-management	10,1	3-5 years	23
43	Wholesale Trade	6			5-10 years	15
48 - 49	Transportation and warehousing	3			10-15 years	1
52	Finance and Insurance	9			15-20 years	1
53	Real estate and rental and leasing	2			>20 years	8
54	Professional, scientific and technical services	12				
56	Water supply and waste management	1				
61	Educational services	5				
62	Health care and social assistance	18				
81	Other services (except public administration)	3				
92	Public services	10				
Missing		7				35
Total		100		100		100

Table 2. Profile of survey respondents

3.2. Measures, scale development and purification

To increase the generalizability and applicability of our research, we adapted the familiar operationalization of Shah & Ward (2007) as a measure of infrastructural Lean practices for both manufacturing and services industries. The final scale includes visual management (VM), pull control (PC), good housekeeping (GH), set-up reduction (SR) and group technology (GT). The constructs supplier feedback, JIT-delivery and supplier development were omitted from the scale due to low values of Cronbach's alpha. Items were estimated through respondents' perceptual evaluation on a five-point Likert scale. The response categories for each item were anchored by 1 (strongly disagree) and 5 (strongly agree); see appendix A1. We evaluated the unidimensionality, reliability and convergent

validity of each scale in this research using confirmatory factor analysis in the software package AMOS 22. For satisfactory convergent validity, the estimated parameters between the latent variables and their indicators should be at least 0.50 (Hair, Anderson, Tatham & Black, 1998) and the average variances extracted (AVE) should also be at least 0.50. Some items have therefore been removed from the final scales. The final second order measurement model of Lean practices fits the data well (Browne & Cudeck, 1992): χ^2 = 95,715, *df*. = 60, p = .002, CFI = 0.962, IFI = 0.963, TLI/NNFI = 0.994, NFI = 0.908, RMSEA = 0.055. Results illustrated in Table A1 in appendix A indicate that convergent validity is supported since all constructs passed these tests.

The variable 'Use of Lean tools' was operationalized using a two-step approach (Brown, 1996). First an extensive literature review search was conducted to generate a list of operational Lean tools (Flex, 2000; Ahmed & Hassan, 2003; Tari & Sabater, 2004; Bamford & Greatbanks, 2005; Clegg, Rees & Titchen, 2010; Tickle, Adebanjo, Mann & Ojadi, 2015; Rivera & Chen, 2007; Belekoukias et al., 2014). Based on a Q-sort procedure, this list was narrowed down by subject matter experts providing content validity for each scale. We developed scales for visual management (Mieruka) tools (VMT), pull control tools (PCT), Kaizen improvement tools (KIT) and Root-cause analysis tools (RCT): see appendix A2. The use of a specific Lean tool was asked with a single question which could be answered with options: not at all; only rarely; occasionally; on a regular basis; extensively. Ultimately only a small part of the initial list of operational Lean tools is included in the final scale, among other things to satisfy the requirement that the average variance extracted is at least 0.50. Table A2 in appendix A reports the testing results of the final second order measurement model of Use of Lean Tools that fits the data well: χ^2 = 32.682, *df*. = 31, p = .384, CFI = 0.997, IFI = 0.997, TLI/NNFI = 0.994, NFI = 0.943 and RMSEA = 0.017.

Process improvement performance (PIP), customer response performance (CRP) and financial performance (FP) were measured using items developed by Choi & Eboch (1998) and Gligor et al. (2015). Respondents were required to indicate what their performance was compared with competitors in their industry with respect to reduction of waste in processes (PIP1), rate of improvement of processes (PIP2), reduction of complexity in processes (PIP3), delivery reliability (CRP1), quick response to customer inquiries (CRP2), speed of complaint handling (CRP3), growth of profit (FP1) and growth of sales revenue (FP2). The items were measured using 5-point Likert scales anchored with 'much worse than competition' and 'much better than competition'. Customer satisfaction performance (CSP) was measured using items developed by Yeung & Ennew (2001), for example 'customers are very satisfied about the quality of our products and/or services'. The response categories for each item of customer satisfaction performance were anchored by 1 (strongly disagree) and 5 (strongly agree); see appendix A for items statistics. Again, we evaluated the unidimensionality, reliability and convergent validity of all Performance variables using confirmatory factor analysis (χ^2= 65.098, *df*. = 29, CFI = .930, IFI = .934, RMSEA = .079; see Table A3), though individual performance scales are used separately in the path model discussed in the next section. Descriptive statistics, Cronbach's alpha and the correlation matrix for all constructs are presented in Table 3. Cronbach's alpha exceeds 0.65 for all constructs, which indicates satisfactory reliability (Cronbach, 1951).

3.3. Control variables and common method bias

We used size as a control variable since smaller organizations typically have fewer resources for process improvement practices like Lean (Cao and Zhang, 2011). Size of the organization was measured by the number of employees (logarithmized). However, we found no significant relationship between size and the constructs in our structural models.

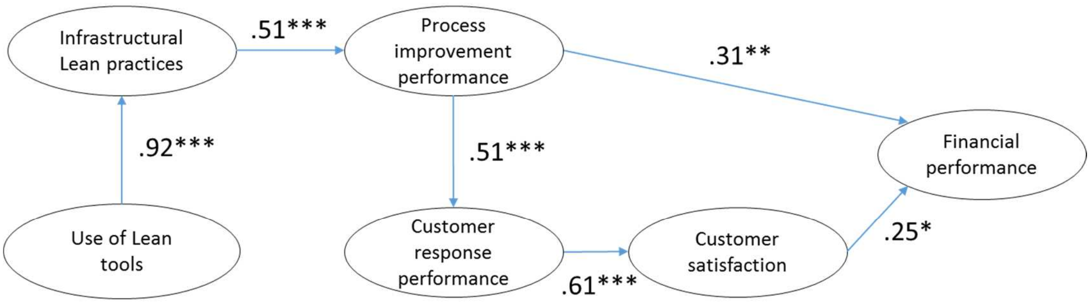
Procedural methods were applied to minimize the potential for common method bias since both the independent and dependent measures were obtained from the same source (Podsakoff and Organ, 1986). Our sample

included predominantly mid- to senior-level managers with significant levels of relevant knowledge, which tends to mitigate single source bias (Mitchell, 1985). Common method bias was also reduced by separating the dependent and independent variable items over the length of the survey instrument and by assuring participants that their individual responses would be kept anonymous (Podsakoff, MacKenzie, Lee & Podsakoff, 2003). We also applied Harman's one-factor test to assess whether common method bias exists (Podsakoff et al., 2003). All variables were entered into an unrotated exploratory factor analysis to test whether the majority of the variance can be explained by a single factor, but this was not the case (27%). We can therefore conclude that the tests of reliability, validity, overall model fit and common method bias provide adequate support for the appropriateness of the model constructs.

4. RESULTS:

4.1. Impact of Use of Lean tools and Lean practices on performance

To estimate the proposed research model, we employed structural equation modelling (SEM). First, we tested two sub-models underlying the hypothesized research model of this paper, namely one that includes the variable Lean practices but not Use of Lean tools, to test the impact of Lean practices on performance and vice versa. Both models showed significant relationships between either Lean practices or Use of Lean tools and process improvement and customer response performance.
Next, we tested a nested model of our hypothesized model, namely one in which Use of Lean tools and Lean practices are presumed to be uncorrelated to simultaneously test the impact of both Lean variables independently on process improvement performance and customer response performance. This model has only significant relationships between Lean practices and process improvement performance (β_{H2} = .55, C.R. = 4.801, p < .001) and Lean practices and customer response performance (β_{H4} = .28, C.R. = 2.183, p < .05), but no significant relationships between Use of Lean tools and process improvement performance or customer response performance. The results of the first two sub-models and this nested model underpin our assumed direction of the path between Use of Lean tools and Lean practices in the hypothesized research model (χ^2 = 676.046, *df.* = 477).



Chi-square = 686.996 IFI = .912 *** p < .001
Degrees of freedom = 480 CFI = .909 ** p < .01
Probability level = .000 RMSEA = .047 * p < .05

Figure 2. Path model between Lean and performance constructs.

We then tested the hypothesized research model with a directed path between Use of Lean tools and Lean practices. Based on the χ^2 difference test ($\Delta\chi^2$ = 128, Δdf = 1, p < .001) we can conclude that the hypothesized model fits the data better than the nested model. Figure 2 shows the final model after the removal of the non-significant paths: χ^2 = 686.996, *df.* = 480, p

= .000, IFI = .912, CFI = .909 and RMSEA = .047. Use of Lean tools is highly related to Lean practices (β_{H1} = .92, C.R. = 7.880, $p < .001$). Lean practices directly impacts process improvement performance (β_{H2} = .51, C.R. = 4.540, $p < .001$) but there is no significant relationship between Lean practices and customer response performance; there is only an indirect relationship (.26). The results also show that the Use of Lean tools only indirectly impacts process improvement performance (.47) and customer response performance (.24). The Lean practices variable is therefore a mediating factor in the relationship between the Use of Lean tools and process improvement performance.

Process improvement performance is directly related to customer response performance (β_{H4} = .51, C.R. = 4.271, $p < .001$) and financial performance (β_{H7} = .31, C.R. = 2.750, $p < .01$). We also tested for a possible direct relationship between customer response performance and financial performance, but found no significant relationship. Customer response performance is directly related to customer satisfaction (β_{H8} = .61, C.R. = 5.153, $p < .001$), which is significantly related with financial performance (β_{H9} = .25, C.R. = 2.431, $p < .05$). Table 4 illustrates the hypothesis testing results.

Hypothesis	Path	Std. Weights (β)	Critical Ratio	Supported?
H1	Lean practices ← Use of Lean tools	0.925	7.880	Yes; $p < .001$
H2	PIP ← Lean practices	0.508	4.540	Yes; $p < .001$
H3	PIP ← Use of Lean tools	− 0.025	−1.176	No; $p = .240$
H4	CRP ← Lean practices	0.49	1.712	No; $p = .087$
H5	CRP ← Use of Lean tools	− 0.057	−0.588	No; $p = .556$
H6	CRP ← PIP	0.508	4.271	Yes; $p < .001$
H7	FP ← PIP	0.313	2.750	Yes; $p < .01$
H8	CS ← CRP	0.613	5.153	Yes; $p < .001$
H9	FP ← CS	0.250	2.431	Yes; $p < .05$

Table 4: Direct effects testing results.

4.2. Moderation analysis: environment

To investigate the moderating influence of the environment (commoditization versus differentiation) in the relationship between Lean practices and process improvement performance, we also asked respondents to rate their perceived importance of standardization in the market (ISAM) and their perceived importance of customer effectiveness in the market (ICEM) for engaging in competition. We consider these variables as proxies for the level of commoditization in the market (i.e. a stable market focusing on standardization and reduction of variability) and the level of differentiation in the market (i.e. a market where variability adaptation and quick response is key); see for instance Pelham (2000) and Ellis (2006).

We first centered the three variables (i.e. ISAM, ICEM and Lean practices) to reduce the threat of multicollinearity (Aiken & West, 1991) and subsequently regressed process improvement performance on ISAM, ICEM, Lean practices, ICEM×Lean practices and ISAM×Lean practices. As both Lean practices and the interaction terms were significant (F = 4.354, b_{10a} = −.460, p < .05 and b_{10b} = .429, p < .05), and multicollinearity was not a problem (VIF values are close to 1; see appendix B for details), we conclude that both ICEM and ISAM moderate the relationship between process improvement performance and Lean practices; see Table 5. However, ISAM enhances the effect of Lean practices on performance, while ICEM weakens the effect of Lean practices on performance; see figures 4 and 5.

Hypothesis	Relationship	Moderator	*b*	Supported
H10	PiP ← Lean practices	ISAM	.429	Yes; $p < .05$
H11	PiP ← Lean practices	ICEM	−.460	Yes; $p < .05$

Table 5. Moderation testing results.

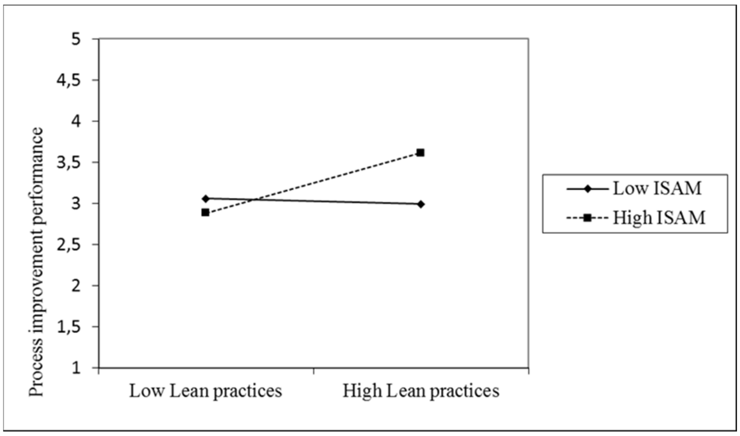


Figure 3. Moderating role of importance of standardization in the market (ISAM). The impact on process improvement performance.

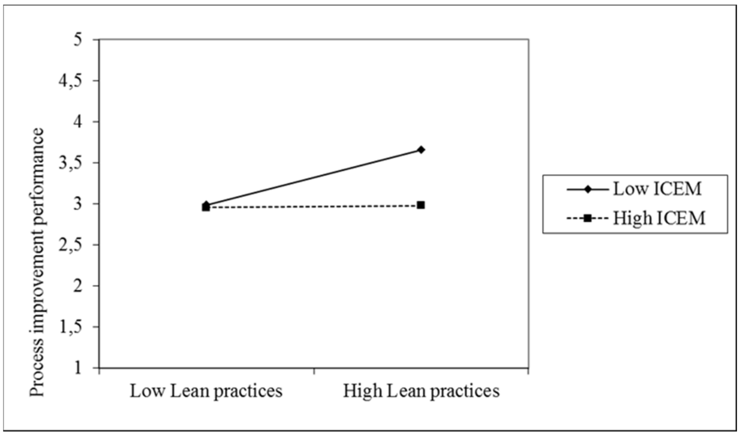


Figure 4. Moderating role of importance of customer effectiveness in the market (ISAM). The impact on process improvement performance.

5. DISCUSSION

5.1. Findings

Lean is broadly classified under the umbrella of process improvement and world class operations, which also include other approaches like business process re-engineering and the theory of constraints (Shah et al., 2008). This study shows that Lean practices directly impact process improvement performance and indirectly impact financial performance, which concurs with the findings of Samson & Terziovski (1999), Nair (2006) and Mackelprang & Nair (2010). However, this study also shows that this relationship is moderated by the type of market. The impact of Lean practices on process improvement performance is enhanced in a market in which standardization is important. Lean is particularly useful in commodity environments with stable and repetitive demand (Hopp & Spearman, 2004). However, this research also shows that, in a market in which customer effectiveness is considered to be important, the impact of Lean practices on process improvement performance is tempered. In other words, in capability markets in which customer effectiveness is perceived to be more important than standardization, the use of Lean practices is still important (since the total effect is still positive), but not so much to reduce complexity and eliminate variability. This line of thinking is reinforced as we did not find a direct relationship between Lean practices and customer response performance. Lean practices add to customer performance and financial performance, but only in an indirect manner.

In this study, we make distinction between Lean practices that constitute infrastructural Lean capabilities and the use of operational Lean tools. Lean practices and the use of Lean tools are of course highly related, but this study shows that the use of Lean tools does not directly impact process improvement performance or customer effectiveness performance, let alone financial performance. This is consistent with the idea that the success of Lean is not due to the use of operational tools (Schonberger, 2007). This study shows that the variable Lean practices is therefore a mediating factor in the relation between the Use of Lean tools and Process improvement performance. In other words, to be effective, the use of Lean tools must be embedded in a bundle of infrastructural Lean practices. Moreover, even though our study is a cross-sectional study, the result gives reason to think that Lean practices are built through the use of operational Lean tools.

5.2. Implications

Increasing operational efficiency does not automatically improve profit (Cooper & Kaplan, 1992); improving financial performance also requires the profitable re-deployment of the resulting slack. However, the reduction of waste and unnecessary or dysfunctional variability (e.g., errors, ineffective systems and poor organization that lead to rework) will result directly in better operational performance, and indirectly in higher customer effectiveness. This paper holds that managers must still decide and use the right tools to implement Lean and improve processes, but the effective use of Lean tools depends on the maturity of the Lean infrastructure. To improve processes, for instance, management should not only encourage the use of appropriate Lean tools, it should also ensure that Lean capabilities are developed (through the introduction and development of Lean practices) whereby a Lean infrastructure is built. The use of Lean tools alone does not lead to the expected success of Lean. What is important is the interaction between the use of Lean tools and developing Lean practices and probably also developing a culture of continuous improvement and Lean Leadership.

5.3. Limitations and future research

As in other empirical studies, the findings and implications in this study should be interpreted with caution, given the methodological limitations of the research, which presents additional future research opportunities. The cross-sectional research design, for instance, limits the extent to which cause-effect relationships can be inferred. This limitation can be addressed in future research through the collection of longitudinal data. Second, since perceptual data is used to measure the constructs of this study, the use of multiple informants to verify perceptions would be a logical extension, especially since the environment was proposed as a moderating variable using participants' perception of the importance of standardization in the market and the importance of customer effectiveness in the market. However, our findings in this respect are consistent with the findings of Azadegan et al. (2013) who also found that environmental complexity positively moderates the effects of Lean operations on performance and that environmental dynamism reduces the benefits of Lean operations on performance.

In this paper, we have examined the interplay between Lean practices and use of operational Lean tools and the impact on process improvement and customer effectiveness performance. However, future research into the interaction between Lean practices, the use of Lean tools and a culture of continuous improvement and Lean Leadership is needed in order to examine possible additional moderating effects.

REFERENCES

Ahire, S.L., Dreyfus, P. (2000). The impact of design management and process management on quality: an empirical investigation. Journal of Operations Management, 18 (5), 549-575.

Aiken, L.S., West, S.G. (1991). Multiple regression: Testing and interpreting interactions. London: Sage.

Ahmed, S., Hassan, M. (2003). Survey and case investigations on application of quality management tool and techniques in SMI's. International Journal of Quality & Reliability Management. 20 (7), 795-826.

Anand, G, Ward, P.T., Tatikonda, M.V., Schilling, D.A. (2009). Dynamic capabilities through continuous infrastructure. Journal of Operations Management, 27, 444-461.

Anderson, R.D., Jerman, R.E., Crum, M.R. (1998). Quality management influences on logistics performance. Logistics and Transportation Review, 34 (2), 137-148.

Anderson, E.W., Fornell, C., Lehman, D.R. (1994). Customer satisfaction, market share, and profitability: findings from Sweden. Journal of Marketing, 58 (3), 53-66.

Atkins, C.H., Dykes, P., Hagerty, J., Hoye, J. (2002). How customer performance partnerships can sharpen your competitive edge. The Journal for Quality and Participation, 25 (3), 22-25.

Azadegan, A., Patel, P.C., Zangoueinezhad, A., Linderman, K. (2013). The effect of environmental complexity and environmental dynamism on Lean practices. Journal of Operations Management, 31, 139-212.

Balakrishnan, R., Linsmeier, T.J., Venkatachalam, M. (1996). Financial benefits from JIT adoption: effects of customer concentration and cost structure. Accounting Review, 71 (2), 183-205.

Bamford, D.R., Greatbanks, R.W. (2005). The use of quality management tools and techniques: a study of application in everyday situations. International Journal of Quality & Reliability Management, 22 (4): 376-392.

Baron, R.M., Kenny, D.A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research – Conceptual, Strategic, and Statistical Considerations. Journal of Personality and Social Psychology, 51 (6), 1173-1182.

Belekoukias, I., Garza-Reyes, J., Kumar, V. (2014) The impact of Lean methods and tools on the operational performance of manufacturing organizations. International Journal of Production Research, 52 (18), 5346-5366.

Bernhardt, K.L., Donthu, N., Kennett, P.A. (2000). A longitudinal analysis of satisfaction and profitability. Journal of Business Research, 47 (2), 161-171.

Bollen, K.A., Long, J.S. (1993). Testing Structural Equation Models, London: Sage Publications.

Brown, S.R. (1996). Q methodology and qualitative research. Qualitative Health Research, 6, 561-567.

Browne, M., Cudeck, R. (1992). Alternative ways of assessing model fit. Sociological Methods Research, 21 (2), 230-258.

Cagliano, R., Caniato, F., Spina, G. (2006). The linkage between supply chain integration and manufacturing improvement programmes. International Journal of Operations & Production Management, 26 (3), 282-299.

Cao, M., Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. Journal of Operations Management, 29 (3), 163-180.

Cepeda, G., Vera, D. (2007). Dynamic capabilities and operational capabilities: A knowledge management perspective. Journal of Business Research, 60 (5), 426-437.

Choi, T.Y., Liker, J.K. (1995). Bringing Japanese continuous improvement approaches to U.S. manufacturing: The roles of process orientation and communications. Decision Sciences, 26, 589-620.

Choi, T.Y., Eboch, K. (1998). The TQM Paradox: relations among TQM practices, plant performance and customer satisfaction. Journal of Operations Management, 17, 59-75.

Claycomb, C., Germain, R., Dröge, C. (1999). Total system JIT outcomes: inventory, organization and financial effects. International Journal of Physical Distribution & Logistics Management, 29 (10), 612-630.

Clegg, B., Rees, C., Titchen, M. (2010). A study into the effectiveness of quality management training: a focus on tools and critical success factors. The TQM Journal, 22 (2), 188-208.

Coyle-Shapiro, J.A.-M. (2002). Changing employee attitudes: the independent effects of TQM and profit sharing on continuous improvement orientation. Journal of Applied Behavioral Science, 38 (1), 57-77.

Cooper, R., Kaplan, R. (1992). Activity-based costing: Measuring the cost of resource usage. Accounting Horizons, 6 (3), 1-14.

Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. Psychometrica, 16 (3), 297-334.

Cua K., McKone, E., Schroeder, R.G. (2001). Relationships between implementation of TQM, JIT, and TPM and manufacturing performance. Journal of Operations Management, 19, 675-694.

Dale, B.D., McQuater, R. (1998). Managing Business Quality Improvement and Quality: Implementing key tools and techniques. Oxford: Blackwell.

Das, A., Handfield, R., Calantone, R., Ghosh, S. (2000). A contingency view of quality management—the impact of international competition on quality. Decision Sciences, 31 (3), 649-690.

Davies, A.J., Kochhar, A.K. (2002). Manufacturing best practice and performing studies: A critique. International Journal of Operations & Production Management, 22, 289-305.

de Treville, S., Antonakis, J. (2006). Could Lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues. Journal of Operations Management 24, 99-123.

Dean, J.W., Bowen, E.C. (1994). Management theory and total quality: improving research and practice through theory development. Academy of Management Review, 19 (3), 392-419.

Done, A., Voss, C., Rytter, N.G. (2011). Best practice interventions: short-term impact and long-term outcomes. Journal of Operations Management, 29, 500-513.

Easton, G.S., Jarrell, S.L. (1998). The effects of total quality management: an empirical investigation. Journal of Business, 71 (2), 253-307.

Ellis, P.D. (2006). Market Orientation and Performance: A Meta-Analysis and Cross-National Comparisons. Journal of Management Studies, 43(5), 1089-1107.

Eroglu, C., Hofer, C. (2010). Lean, Leaner, Too Lean? The Inventory–Performance Link Revisited. Journal of Operations Management 29(4), 356-369.

Feld, W.M. (2000). Lean Manufacturing: Tools, Techniques, and How to Use Them, Boca Raton: St. Lucie Press.

Flex, M.W. (2000). Lean manufacturing: tools, techniques and how to use them, Boca Raton: St. Lucie Press.

Flynn, B.B., Sakakibara, S., Schroeder, R.G. (1995). Relationship between JIT and TQM: practices and performance. Academy of Management Journal, 38 (5), 1325-1360.

Flynn, B.B., Saladin B. (2001). Further evidence on the validity of the theoretical models underlying the Baldridge criteria. Journal of Operations Management, 19 (6), 617-652.

Flynn, B.B., Flynn, E.J. (2004). An exploratory study of the nature of cumulative capabilities. Journal of Operations Management, 22(5), 439-457.

Fullerton, R.R., McWatters, C.S. (2001). The production performance benefits from JIT implementation. Journal of Operations Management, 19, 81-96.

Fullerton, R.R., McWatters, C.S., Fawson, C. (2003). An examination of the relationships between JIT and financial performance. Journal of Operations Management 21 (4), 383-404.

Fullerton, R.R., Wempe, W.F. (2009). Lean manufacturing, non-financial performance measures, and financial performance.

International Journal of Operations and Production Management, 29, 214-240.

Gligor, D.M., Esmark, C.L., Holcomb, M.C. (2015). Performance outcomes of supply chain agility: when should you be agile?. Journal of Operations Management, 33-34, 71-82.

Gustafsson, A., Johnson, M.D. (2002). Measuring and managing the satisfaction—loyalty-performance links at Volvo. Journal of Targeting, Measurement and Analysis for Marketing, 10 (3), 249–259.

Gustafsson, A., Nilsson, L. (2003). The role of quality practices in service organizations. International Journal of Service Industry Management, 14 (2), 232-44.

Green Jr., K.W., Inman, R.A., Birou, L.M., Whitten, D. (2014). Total JIT (T-JIT) and its impact on supply chain competency and organizational performance. International Journal of Production Economics, 147, 125-135.

Hair Jr., J.F., Anderson, R.E., Tatham, R.L., Black, W.C. (1998). Multivariate Data Analysis. 5th ed. Upper Saddle River: Prentice Hall.

Heskett, J., Jones, T., Loveman, G., Sasser, W., Schlesinger, L. (1994). Putting the service-profit chain to work, Harvard Business Review, 72 (2), 164-174.

Hines, P., Holweg, M., Rich, N. (2004). Learning to evolve – A review of contemporary Lean thinking. International Journal of Operations & Production Management, 24 (10), 994-1011.

Hopp, W.J., Spearman, M.L. (2004). To pull or not to pull: what is the question? Manufacturing & Service Operations Management, 6 (2), 133-148.

Huson, M., Nanda, D. (1995). The impact of just-in-time manufacturing on firm performance in the US. Journal of Operations Management, 12 (3–4), 297-310.

Ichniowski, C., Shaw, K. (1997). The effects of human resource management practices on productivity: a study of steel finishing lines. American Economic Review, 87, 291-314.

Ittner, C.D., Larcker, D. (1997). The performance effects of process management techniques. Management Science, 43, 522-534.

Jayaram, J., Vickery, S., Dröge, C. (2008). Relationship building, Lean strategy and firm performance: An exploratory study in the automotive supplier industry. International Journal of Production Research, 46(20), 5633-5649.

Krafcik, J.F. (1988). Triumph of the Lean production system. MIT Sloan Management Review, 30(1), 41.

Ketokivi, M.A., Schroeder, R.G. (2004). Perceptual measures of performance: fact or fiction? Journal of Operations Management, 22 (3), 247-264.

Kumar, V., Batista, L., Maull, R. (2011). The Impact of Operations Performance on Customer Loyalty. Service Science, 3 (2), 158-171.

LaGanga, L.R. (2011). Lean service operations: Reflections and new directions for capacity expansion in outpatient clinics. Journal of Operations Management 29,422-433.

Landry, S., Beaulieu, M. (2010). Achieving Lean healthcare by combining the two-bin kanban replenishment system with RFID technology. International Journal of Health Management and Information, 1 (1), 85-98.

Lin, S.-P. , Yang, C.-L., Chan, Y., Sheu, C. (2010). Refining Kano's 'quality attributes-satisfaction' model: A moderated regression approach. International Journal of Production Economics, 126 (2), 255-263.

MacDuffie, J.P. (1997). The road to ''root cause'': Shop-floor problem solving at three auto assembly plants, Management Science, 43 (4), 479-502.

Mackelprang, A.W., Nair, A. (2010). Relationship between just-in-time manufacturing practices and performance: a meta-analytic investigation. Journal of Operations Management, 28 (4), 283-302.

McLachlin, R. (1997). Management initiatives and just-in-time manufacturing. Journal of Operations Management, 15, 271-292.

Mentzer, J.T., Flint, D.J. (1997). Validity in Logistics Research. Journal of Business Logistics, 18 (1), 199-216.

Meredith, J.O., Grove, A.L., Walley, P., Young, F., Macintyre, M.B. (2011). Are we operating

effectively? A Lean analysis of operating theatre changeovers. Operations Management Research, 4, 89-98.

Mitchell, T.R. (1985). An evaluation of the validity of correlational research conducted in organizations. Academy of Management Review, 10(2), 192-205.

Narasimhan, R., Swink, M., Kim, S.W. (2006). Disentangling Leanness and agility: An empirical investigation. Journal of Operations Management, 24, 440-457.

Nair, A. (2006). Meta-analysis of the relationship between quality management practices and firm performance – implications for quality management theory development. Journal of Operations Management, 24 (6), 948-975.

Naylor, J.B, Naim, M.M., Berry, D. (1999). Leagility: Integrating the Lean and agile manufacturing paradigms in the total supply chain. International Journal of Production Economics 62, 107-118.

Netland, T.H., Schloetzer, J.D., Ferdows, K. (2015). Implementing corporate Lean programs: the effect of management control practices. Journal of Operations Management, 36), 90-102.

Oliver, N., Delbridge, R., Jones, D., Lowe, J., (1994). World class manufacturing: Further evidence in the lean production debate. British Journal of Management, 5, S53–S63.

Pavnaskar, S.J., Gershenson, J.K., Jambekar, A.B, (2003). Classification scheme for lean manufacturing tools. International Journal of Production Research, 41, 3075-3090.

Pelham, A.M. (2000). Market orientation and other potential influences on performance in small and medium-sized manufacturing firms. Journal of Small Business Management, 38 (1): 48-67.

Peng, D.X., Schroeder, R.G., Shah, R. (2008). Linking routines to operations capabilities: A new perspective. Journal of Operations Management, 26, 730-748.

Podsakoff, P.M., Organ, D.W. (1986). Self-reports in organizational research: problems and prospects. Journal of Management, 12, 531-544.

Podsakoff, P.M., MacKenzie, S.B., Lee, J., Podsakoff, N.P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. Journal of Applied Psychology, 88 (5), 879-903.

Rivera, L., Chen, F.F. (2007). Measuring the impact of Lean tools on the cost–time investment of a product using cost–time profiles. Robotics and Computer-Integrated Manufacturing 23, 684-689.

Sakakibara, S., Flynn, B.B., Schroeder, R.G., Morris, R.T. (1997). The impact of just-in-time manufacturing and its infrastructure on manufacturing performance. Management Science 43 (9), 1246-1257.

Samson, D., Terziovski, M. (1999). The relationship between total quality management practices and operational performance. Journal of Operations Management, 17 No 4: 393-409.

Sanchez, A.M., Perez, M.P. (2001). Lean indicators and manufacturing strategies. International Journal of Operations & Production Management, 21, 1433-1451.

Schonberger, R.J. (2007). Japanese production management: An evolution—With mixed success. Journal of Operations Management, 25(2), 403-419.

Schonberger, R.J. (1983). Applications of Single-Card and Dual-Card Kanban. Interfaces, 13(4), 56-67.

Shah, R., Ward, P.T. (2003). Lean manufacturing: context, practice bundles, and performance. Journal of Operations Management, 21 (2), 129-150.

Shah, R., Ward, P.T. (2007). Defining and developing measures of Lean production. Journal of Operations Management, 25, 785-805.

Shah, R., Chandrasekaran, A., Linderman, K. (2008). In pursuit of implementation patterns: the context of Lean and Six Sigma. International Journal of Production Research, 46 (23), 6679-6699.

Sila, I., Ebrahimpour, M. (2003). Examination and comparison of the critical factors of total quality management (TQM) across countries.

International Journal of Production Research 41, 235-268.

Sila, I. (2007). Examining the effects of contextual factors on TQM and performance through the lens of organizational theories: an empirical study. Journal of Operations Management, 25 (1), 83-109.

Sitkin, S.B., Sutcliffe, K.M., Schroeder, R.G. (1994). Distinguishing Control from Learning in Total Quality Management: A Contingency Perspective. The Academy of Management Review 19, 537-564.

Sosik, J.J., Dionne, S.D. (1997). Leadership styles and Deming's behavior factors. Journal of Business and Psychology, 11, 447-462.

Spear, S.J., Bowen, H.K. (1999). Decoding the DNA of the Toyota Production System. Harvard Business Review, September-October, 96-106.

Sutcliffe, K., Sitkin, S., Browning, L. (2000). Tailoring process management to situational requirements: beyond the control and exploration dichotomy. In: Cole, R., Scott, W.R. (Eds.). The Quality Movement and Organization Theory. Thousand Oaks: Sage, 315-330.

Swank, C.K. (2003). The Lean service machine. Harvard Business Review, October, 123-129

Takeuchi, H., Osono, E., Shimizu, N. (2008). The contradictions that drive Toyota's success. Harvard Business Review, June, 96-103.

Tari. J.J., Sabater, V. (2004). Quality tools and techniques: are they necessary for quality management? International Journal of Production Economics, 92 (3), 267-280.

Thun, J.H., Druke, M., Grubner, A. (2010). Empowering Kanban through TPS-principles - an empirical analysis of the Toyota Production System. International Journal of Production Research, 48 (23), 7089-7106.

Tickle, M., Adebanjo, D., Mann, R., Ojadi, F. (2015). Business improvement tools and techniques: a comparison across sectors and industries. International Journal of Production Research, 53 (2), 354-370.

Tu, Q., Vonderembse, M.A., Nathan, T.S.R. (2001). The impact of time-based manufacturing practices on mass customization and value to customer. Journal of Operations Management, 19, 201-217.

Tyagi, S., Choudhary, A., Cai, X., Yang, K. (2015). Value stream mapping to reduce the lead-time of a product development process. International Journal of Production Economics 160, 202-212.

White, R.E., Pearson, J.N., Wilson, J.R. (1999). JIT Manufacturing: A survey of implementation in small and large US manufacturers. Management Science, 45 (1), 1-15.

Wilson, D.D., Collier, D.A. (2000). An empirical investigation of the Malcolm Baldrige National Quality award causal model. Decision Sciences, 31 (2), 361-383.

Wright, P.M., Snell, S.A. (2002). Research update. Human Resource Planning, 25 (2), 45-54.

Womack, J.P., Jones, D.T., Roos, D. (1990). The machine that changed the world. New York: Simon & Schuster.

Womack, J.P., Jones, D.T. (1996). Lean thinking: Banish waste and create wealth in your corporation. New York: Simon & Schuster.

Yeung, M.C.H., Ennew, C.T. (2001). Measuring the impact of customer satisfaction on profitability: a sectoral analysis. Journal of Targeting, Measurement and Analysis for Marketing, 10 (2), 106-117.

Table 3. Descriptive statistics and correlation matrix with Cronbach's alpha on the diagonal.

	Mean	S.D.	VMT	PCT	KIT	RCI	Use of Lean tools	SR	VMC	PC	GH	GT	Lean Practices	PIP	CSP	FP	CRP	ISAM	ICEM	FS
Visual management tools (VMT)	1.79	1.10	0.708																	
Pull control tools (PCT)	1.24	0.64	.422**	0.709																
Kaizen improvement tools (KIT)	2.03	1.06	.335**	.370**	0.808															
Root-cause analysis tools (RCT)	1.57	0.92	.552**	.480**	.320**	0.684														
Use of Lean tools	**1.66**	**0.68**	**.764****	**.741****	**.659****	**.772****	**0.689**													
Set-up-reduction (SR)	2.59	0.79	.423**	.372**	.238*	.312**	.432**	0.846												
Visual management (VM)	2.75	0.95	.646**	.404**	.363**	.457**	.597**	.527**	0.735											
Pull control (PC)	2.52	0.94	.449**	.505**	.254**	.485**	.499**	.543**	.576**	0.848										
Good housekeeping (GH)	2.15	1.03	.488**	.659**	.396**	.686**	.733**	.392**	.468**	.596**	0.891									
Group Technology (GT)	3.37	0.80	.319**	.194*	.133	.316**	.341**	.322**	.419**	.320**	.281**	0.700								
Lean Practices	**2.67**	**0.70**	**.678****	**.657****	**.399****	**.694****	**.779****	**.720****	**.831****	**.840****	**.799****	**.628****	**0.824**							
Process improvement performance (PIP)	3.16	0.68	.285**	.159	.121	.210	.278*	.272*	.310**	.361**	.359**	.120	.383**	0.776						
Customer satisfaction performance (CSP)	3.71	0.70	.066	.167	.014	.000	.130	.370**	.140	.132	.104	.134	.272*	.219*	0.796					
Financial performance (FP)	3.40	0.83	.123	.143	.004	.081	.154	.129	.229**	.363**	.226*	.040	.325**	.234*	.258**	0.849				
Customer response performance (CRP)	3.54	0.67	.157	.333**	.102	.114	.330**	.404**	.225*	.308**	.228*	.162	.379**	.391**	.438**	.410**	0.693			
Importance of standardization (ISAM)	3.60	0.72	.141	.003	.121	-.018	.056	.211*	.068	.062	-.102	.171*	.058	.015	-.030	.162	-.055	0.820		
Importance of customer effectiveness (ICEM)	4.21	0.65	.002	.091	-.021	-.089	-.052	.084	-.024	-.191*	-.050	.181*	-.156	.028	.117	.056	-.016	.320**	0.756	
Size (logarithmized) (FS)	2.99	0.88	-.012	-.008	.136	.011	.100	-.137	.107	.020	-.027	.048	.030	-.060	-.019	-.092	-.023	.072	.067	-

** $p < 0.01$ level (2-tailed).
* $p < 0.05$ level (2-tailed).

APPENDIX A: SURVEY ITEMS & RELIABILITY AND ITEM STATISTICS

A.1. Lean practices

Set-up-reduction (SR)
Range: strongly disagree – strongly agree (5-point Likert scale)
In this business unit (location, department)…

SR1 employees are trained to reduce set-up time
SR2 we have a structured method to reduce set-up time
SR3 we continuously *try to* reduce set-up time

Visual management (VM)
Range: strongly disagree – strongly agree (5-point Likert scale)
In this business unit (location, department)…

VM1 signs, symbols and lines are used to indicate how process run, where material deliveries take place, what the walking paths are and where stock locations are.
VM2 a visual control system is present at the workplace that provides information about the production, quality and / or backlog.
VM3 information screens (that can been seen by everyone) are present that show performances (daily or weekly performance).
VM4 *up-to-date work instructions are present in any workplace and visualized by using characters (symbols), photos, and procedures.* - not included in the final scale to increase AVE

Pull control (PC)
Range: strongly disagree – strongly agree (5-point Likert scale)
In this business unit (location, department)…

PC1 *we have a method to keep the work in progress in the primary processes low and evenly (so that work flow and peaks are avoided).* - not included in the final scale to increase AVE
PC2 we work with pull-control, in which production is initiated from a real customer order.
PC3 we use a pull-control system
PC4 work at a particular machine / workstation is triggered by a pull-signal from a subsequent machine / workstation.

Good housekeeping (GH)
Range: strongly disagree – strongly agree (5-point Likert scale)
In this business unit (location, department)…

GH1 all employees know what the 5S method.
GH2 *for every workstation / workplace it is made clear what resources and tools are needed and what is actually 'unnecessary' to have present at the workplace.* - not included in the final scale
GH3 everyone in the organization knows why 5S has been introduced and applied
GH4 *all 'unnecessary' items removed (such as unused tools, rejected materials or scrap, personal materials, outdated information).* - not included in the final scale to increase AVE

Group technology (GT)
Range: strongly disagree – strongly agree (5-point Likert scale)
In this business unit (location, department)…

GT1 *resources and/or workstations are grouped in such a way that each product family can be produced in a continuous flow* - not included in the final scale to increase AVE
GT2 products and/or services are grouped by routing and/or similar process steps.
GT3 products and/or services are grouped according similar activities and actions to produce the products and/or services

Table A.1. Reliability and item statistics for second order measurement model of Lean practices (Chi-square = 95,715, *df.* = 60, *p* = .002, CFI = 0.962, IFI = 0.963, TLI/NNFI = 0.994, NFI = 0.908, RMSEA = 0.055).

	Cronbach alpha for scale	Alpha if item deleted	Item-to-total correlation	Mean	SD	Item loadings	Average Variances Extracted
Set-up Reduction	0.846						0.610
SRC1		0.750	.752	2.59	.902	0.775	
SRC2		0.835	.665	2.49	.964	0.747	
SRC3		0.773	.727	2.69	.911	0.82	
Visual	0.735						0.521
VMC1		0.667	.445	2.57	1.177	0.589	
VMC2		0.571	.597	2.73	1.100	0.776	
VMC3		0.556	.611	2.73	1.176	0.784	
Pull Control	0.848						0.663
PCC2		0.724	.650	2.56	1.192	0.775	
PCC3		0.675	.755	2.51	1.009	0.875	
PCC4		0.712	.674	2.36	1.052	0.789	
Good	0.891						0.802
GHC1			.635	1.86	1.014	0.886	
GHC3			.626	2.05	.989	0.905	
Group Tech	0.700						0.538
GTC2			.528	3.37	.953	0.754	
GTC3			.527	3.38	.930	0.712	
LeanInfra							0.511
Chi-square =	CFI	0,962		Set-up Reduction		0.739	
df. = 60	IFI	0,963		Visual Management (VMC)		0.831	
p = ,002	TLI/NNFI	0,994		Pull Control (PCC)		0.763	
	NFI	0,908		Good Housekeeping (GHC)		0.654	
	RMSEA	0,055		Group Technology (GTC)		0.557	

A.2. Use of Lean tools

Rage: 5-point Likert scale and the answering option 'Do not know'
1 – No, not at all, 2 – Yes, but only rarely, 3 – Yes, occasionally, 4 - Yes, on a regular basis, 5 – Yes, extensively

In this business unit (location, department) we make use of…

Visual management tools
VMT1 glass walls and/or white boards with performance indicators
VMT2 value stream maps on the shop floor and/or within the office
VMT3 visual quality control charts - not included in the final scale to increase AVE

Pull control tools
PCT1 kanban cards (system)
PCT2 two-bin cards (system)
PCT3 takt times

Kaizen improvement tools
KIT1 PDCA improvement cycle
KIT2 Large kaizen events (kaizen improvement sessions that take longer than 1 day)
KIT3 Small kaizen bubbles (improvement sessions that take no longer than 1 day)

Root-cause analysis tools
RCT1 Fish-bone diagram (cause-and-effect diagrams)
RCT2 5Why's method

Table A.2. Reliability and item statistics for second order measurement model of Use of Lean Tools (chi-square = 32.682, *df.* = 31, *p* = .384, CFI = 0.997, IFI = 0.997, TLI/NNFI = 0.994, NFI = 0.943, RMSEA = 0.017).

	Cronbach alpha for scale	Alpha if item deleted	Item-to-total correlation	Mean	SD	Item loadings
Visual management tools	0.708					
VMT1			.504	2.06	1.517	0.754
VMT2			.504	1.8	1.222	0.673
Pull control tools	0.709					
PCT1		0.548	.582	1.27	.837	0.780
PCT2		0.635	.514	1.22	.832	0.753
PCT3		0.666	.487	1.27	.797	0.721
Kaizen improvement tools	0.808					
KIT1		0.888	.527	2.95	1.506	0.567
KIT2		0.617	.779	1.79	1.276	0.939
KIT3		0.703	.694	1.86	1.288	0.856
Root-cause analysis tools	0.684					
RCT1			.537	1.61	1.011	0.594
RCT2			.537	1.65	1.307	0.976
LeanTools	CFI	0,997				
Chi-square = 32,682	IFI	0,997		Visual management tools		0.872
df. = 31	TLI/NNFI	0,994		Pull control tools		0.878
p = ,384	NFI	0,943		Kaizen tools		0.586
	RMSEA	0,017		Root-cause analysis toolsInstr.		0.825

A.3. Performance

Process improvement performance (PIP)
Compared to the competitors in your industry, how does your organization perform on:
Range: much worse than competition – much better than competition (5-point Likert scale)
PIP1 Reduction of waste in processes
PIP2 Rate of improvement of processes
PIP3 Reduction of complexity in processes

Customer response performance (CRP)
Compared to the competitors in your industry, how does your organization perform on:
Range: much worse than competition – much better than competition (5-point Likert scale)
CRP1 Delivery reliability
CRP2 Quick response to customer inquiries
CRP3 Speed of complaint handling - not included in the final scale to increase AVE

Financial performance (FP)
Compared to the competitors in your industry, how does your organization perform on:
Range: much worse than competition – much better than competition (5-point Likert scale)
FP1 Growth of profit
FP2 Growth of sales revenue

Customer satisfaction performance (CSP)
Range: strongly disagree – strongly agree (5-point Likert scale)
CSL1 Customers are very satisfied about the quality of our products and/or services.

CSL2 Customers are very satisfied about the characteristics and functionality of our products and/or services.
CSL3 Customers are very loyal to the use and repeat purchase of our products and/or services. - not included in the final scale to increase AVE
CSL4 Customers recommend us to other potential customers to buy our products and / or services.

Table A.3. Reliability and item statistics for measurement model of Performance (chi-square = 65.098 *df.* = 29, CFI = .930, IFI = .934, RMSEA = .079).

	Cronbach alpha for scale	Alpha if item deleted	Item-to-total correlation	Mean	SD	Item loadings	Average Variances Extracted
PIP	0.776						0.540
PIP1		0.722	.588	3.07	.791	.718	
PIP2		0.717	.601	3.32	.893	.721	
PIP3		0.655	.655	3.08	.761	.765	
CRP	0.693						0.529
CRP1			.531	3.57	.752	.790	
CRP2			.531	3.50	.784	.659	
FP	0.849						0.762
FP1			.743	3.30	.950	.962	
FP2			.743	3.49	.838	.774	
CSP	0.796						0.567
CSP1		0.698	.663	3.87	.846	0.787	
CSP2		0.703	.661	3.74	.791	0.796	
CSP4		0.767	.600	3.53	.864	0.669	

APPENDIX B: MODERATION ANALYSIS

We followed a procedure for moderation Baron and Kenny (1986) using the software package SPSS22. Respondents were asked to rate the importance of standardization and customer effectiveness to compete in the market.

Importance of standardization in the market (ISAM)
How important are the following market priorities / capabilities in your industry to serving competition
Range: very unimportant – very important (5-point Likert scale)
ISM1 of total product / service offerings (mean)
ISM2 Reduction of variation in work processes
ISM3 Standardization of processes
ISM4 Reduction of waste in processes
ISM5 Reduction of complexity in processes

Importance of customer effectiveness in the market (ICEM)
How important are the following market priorities / capabilities in your industry serving competition
Range: very unimportant – very important (5-point Likert scale)
ICM1 Customer satisfaction
ICM2 Quick response to customer inquiries
ICM3 Speed of complaint handling

Table B.1. Reliability and item statistics.

	Cronbach alpha for scale	Alpha if item deleted	Item-to-total correlation	Mean	S.D.
ISAM	0.820				
ISAM1		*.800*	*.540*	3.45	1.016
ISAM2		*.749*	*.707*	3.36	.910
ISAM3		*.745*	*.726*	3.64	.870
ISAM4		*.801*	*.524*	3.82	.855
ISAM5		*.796*	*.560*	3.72	1.077
ICEM	0.756				
ICEM1		*.677*	*.581*	4.47	.759
ICEM2		*.685*	*.573*	4.09	.767
ICEM3		*.654*	*.602*	4.02	.836

Table B.1. Results of regression to test mediating effects.

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	,532[a]	,284	,218	,56588	,284	4,354	5	55	,002

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6,971	5	1,394	4,354	,002
	Residual	17,612	55	,320		
	Total	24,583	60			

Coefficients

		Unstandardized Coefficients		Standardized Coefficients			Correlations			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	3,116	,074		41,991	,000					
	ISAMC	,119	,108	,131	1,098	,277	,144	,146	,125	,909	1,101
	ICEMC	-,029	,155	-,025	-,190	,850	-,144	-,026	-,022	,769	1,300
	LeanPracticesC	,259	,127	,264	2,030	,047	,417	,264	,232	,768	1,302
	LeanPracticesC *x* ICEMC	-,460	,225	-,288	-2,046	,046	-,211	-,266	-,234	,657	1,523
	LeanPracticesC *x* ISAMC	,429	,200	,303	2,146	,036	,297	,278	,245	,653	1,532

Dependent Variable: Process improvement performance

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