Statistical investigation of moderation on soft lean practices

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Abstract

As soft lean practices (SLP) we intend those lean practices that are related to people engagement and development, promoting the human side of lean. In this paper we intend to investigate the relationship between SLP and operational performance and in particular if these practices are more efficacious in manufacturing contexts with high degree of repetitiveness of production. Data were analysed from the High Performance Manufacturing (HPM) project dataset using hierarchical regression and structural equation modelling (SEM). The analyses suggest that the degree of repetitiveness of the production system significantly moderate the impact of SLP on operational performance.

Keywords: Lean, soft practices, High Performance Manufacturing

1. Introduction

Lean Management (LM) can be defined as a complex set of socio-technical practices, focused on streamlining the production flow through reduction of physical redundancies, and more in general "wastes", and through continuous improvement (Shah and Ward, 2003). At an operational level, lean practices can be grouped into four interrelated bundles: just in time (JIT), meant to reduce "wastes", in particular stocks and delays; total quality management (TQM), focused on quality continuous improvement; total preventive maintenance (TPM), aimed at maximizing equipment effectiveness through preventive maintenance; human resource management (HRM) practices intended to ensure a flexible and versatile workforce committed to continuous improvement. These bundles imply the distinction between hard and soft lean practices (SLP) (Bortolotti, Boscari & Danese, 2015). Hard practices are those technical and analytical lean tools, whereas soft practices are related to employee empowerment, problem solving and team working.

In general, LM has been associated with better operational performance (Hines, Holweg & Rich, 2004). The most cited outcomes are reduction of inventories and lead time, better process and product quality and increased flexibility in customer response.

Investigation of contingencies and characteristics affecting the implementation of lean bundles has been also studied as regards JIT, TQM, and TPM (Sila, 2007; Bortolotti, Danese & Romano, 2013; White & Prybutok, 2001; McKone, Schroeder & Cua, 1999; Shah & Ward, 2003; Prajogo & Sohal, 2006). However, in lean literature, poor attention has been payed on what aspects affect the impact of SLP on performance (Zeng, Anh Phan & Matsui, 2015), despite the central role of these elements in the TPS (Sugimori *et al.*, 1977), and in general in other company-specific production systems (Netland, 2012). A debate has been recently opened regarding the effect of SLP outside automotive industries (Marin-Garcia & Bonavia, 2015; Portioli-Staudacher & Tantardini, 2012).

The purpose of this paper is to overcome the universalistic claim that SLP are equally effective in every production context. In particular, we aim to investigate the relationship between SLP and operational performance and if these practices are more efficacious in manufacturing contexts with high degree of repetitiveness of production.

Section 2 introduces the importance of SLP and their link with performance. In section 3 we present the influence of manufacturing repetitiveness on this relationship. In section 4 empirical data supporting the hypotheses are provided and in section 5 we discuss the results.

2. Soft lean practices and performance

For SLP we intend those practices that are related to people engagement and development, promoting the human side of LM (Bortolotti, Boscari & Danese, 2015; Zeng, Anh Phan & Matsui, 2015). It has been recognized that SLP play a key role in reaching and maintaining a superior performance through lean production (Hines, Holweg & Rich, 2004; Bortolotti, Boscari & Danese, 2015).

Since early investigation on lean and just-in-time, researchers have recognized the importance of human-centered practices and their connection with performance (MacDuffie, 1995; Sugimori *et al.*, 1977). However, SLP still represent an interesting research topic, due to the fact that many lean journeys still fail because of scarce interest in employees involvement (Pay, 2008) and lean implementations may have potentially harmful effects in matter of workers' health when overlooking human-related practices (de Treville & Antonakis, 2006; Longoni, Golini & Cagliano, 2014).

Starting from Zeng et al.'s research on soft quality management (2015), the focus of the present study is on specific lean practices related to workers' involvement and continuous improvement.

In particular, following an approach similar to Zeng et al.'s one, in the current research, small group problem-solving and employee suggestions have been used to capture the concept of SLP. Small group problem-solving refers to the common practice of creating temporary multifunctional teams in order to address a specific operational problem (Flynn, Schroeder & Sakakibara, 1994). Employee suggestions regard the practice of introducing and using a plant suggestions program encouraging employees to provide concrete solutions to everyday problems (MacDuffie, 1995). In addition to these, it was decided to include continuous improvement as a fundamental element of employees' involvement in LM. Defined as the organizational propensity to pursue improvements in products or processes (Huang, Rode & Schroeder, 2011), continuous improvement (also called kaizen), together with employee suggestions and small group problem-solving, allows to consistently measure soft lean practices oriented to people involvement.

In general, in the literature the three included practices are associated with a better operational performance (Zeng, Anh Phan & Matsui, 2015; Shah & Ward, 2003; MacDuffie, 1995), and thus we advance Hypothesis 1:

Hypothesis 1: SLP positively impact on operational performance

3. Soft lean practices and repetitiveness of production

Repetitiveness of production systems

Volume and variety are two important aspects determining the characteristics of the production systems (Hayes & Wheelwright, 1979). A non-repetitive context is defined by a high variety of manufactured products and by a low volume for each product. The company strategy, in terms of cost, quality and flexibility (Voss, 1995) is strictly related to the variety-volume mix. Non-repetitive manufacturing companies generally compete in terms of differentiation, adopting a coherent manufacturing system, such as job shop or production cells with a flexible work-force, that allows the production of a broad variety of products. Differently, in repetitive contexts with a low product variety and high volumes per product, companies are very cost-oriented and use more repetitive production systems, such as mixed lines or fully dedicated lines.

In this research, the degree of repetitiveness of the production has been detected measuring the predominant manufacturing configuration, from job shop to dedicate lines.

Soft lean practices and repetitiveness of production systems

In their seminal contribution, Shah and Ward (2003) have shown that lean HRM bundle-performance relationship is not affected by the manufacturing type defined through contraposition of process industry plants and discrete industry plants, suggesting a universalistic perspective regarding the effectiveness of these practices in all these manufacturing contexts.

However, a debate has been recently opened regarding the effect of soft lean practices (and lean in general) outside automotive industries in production systems with different characteristics (Marin-Garcia & Bonavia, 2015; Portioli-Staudacher & Tantardini, 2012). For example, it has been recently shown by Bonavia and Marin-Garcia (2015) that lean-related human resource practices have a significant impact on performances also in rigid continuous process industry, such as the ceramic one.

Moreover, through a single case study, Lander and Liker (2007) showed that lean, when implemented coherently with a strong focus on continuous improvement and people involvement, works and leads to significant performance improvements, even in low-repetitiveness contexts.

Looking at HRM literature, the critical role of contingencies has been recognized in affecting the implementation of human resource practices and their link with performances (Boselie, Dietz & Boon, 2005).

In particular, it has been supported that the company strategy in terms of cost, quality or flexibility orientation might affect the impact of HRM practices on firm performances (Youndt *et al.*, 1996).

Given the fit between strategy and production models, where cost efficiency strategies are more frequently associated with high repetitive production systems and differentiation strategies with less repetitive configurations, this finding suggests that production systems may affect the impact of SLP on operational performance.

Based on these contradictory findings, we intend to examine whether production system repetitiveness influences the relationship between SLP and operational performance.

We hypothesize that SLP are more effective in more repetitive production contexts rather than in contexts with low repetitiveness.

Hypothesis 2: The degree of repetitiveness of the production system moderates positively the impact of SLP on operational performance

We derived our hypothesis from the literature, following two distinct arguments supporting that high repetitive production environments are more sensitive to SLP in term of performance improvement.

Our first argument is related to the fact that high repetitive production systems are characterized by higher demanding working conditions. This may reinforce the positive impact of SLP on performance, through employee well-being enhancement.

Since the introduction of the assembly line in Ford in the early 20th century, high repetitive production systems have been generally characterized by high work-pace, highly standardised jobs, reduced discretion and choice autonomy – i.e. freedom concerning procedures and time, also in lean environments (Parker, 1998, 2003; de Treville & Antonakis, 2006; Schultz *et al.*, 1998).

The scarce amount or absence of inventories between phases and the strict synchronization among workers exert a strong pressure on employees, typical of high repetitive production systems, even more exacerbated in lean contexts (Cullinane *et al.*, 2014; Schultz *et al.*, 1998).

Drawing upon organizational psychology literature, we can affirm that these contexts, compared to low repetitive production systems, are characterized by higher levels of job demands, defined as those job aspects requiring continuous physical or mental efforts (e.g. work-pressure), and lower levels of job resources, defined as those job aspects supporting and stimulating personal development (e.g. autonomy, discretion), (Demerouti *et al.*, 2001).

In accordance with the job demands-resource model (Demerouti *et al.*, 2001; Bakker *et al.*, 2007), job resources have the potential to improve workers well-being, in particular when job demands are high.

In agreement with this perspective, Conservation of Resource Theory (Hobfoll, 2002) affirms that additional resources have themselves only a modest effect, though they acquire relevance in a resource loss context.

In this sense, we can hypothesized that in high repetitive environments, characterized by a high work pressure (high level of demands), incremental job resources made available by SLP in terms of responsible autonomy – i.e. increase in accountability arising from decentralization of authority, power sharing, and participation in decision making (de Treville & Antonakis, 2006) – have an higher potential to improve employee well-being in comparison to less repetitive production systems.

In turn, this increase in employee wellbeing can be congruent and linked with better organizational performances in agreement with a "mutual gains perspective" that links HRM to both better employee well-being and better organisational performance (Van De Voorde, Paauwe & Van Veldhoven, 2012).

According to this view, HRM increases employee well-being related outcomes such as job satisfaction and commitment which then positively affect organizational performance.

Following a similar framework of those proposed by de Treville and Anotanikis (2006), but inspired by the job demands-resources model research in lean contexts (Cullinane *et al.*, 2014), we hypothesized that SLP affect indirectly operational performances increasing job resources and consequently employee well-being in the shop floor (H1). This relationship is moderated by the degree of repetitiveness of the production system, through the increase of job demands (H2) (Figure 1).

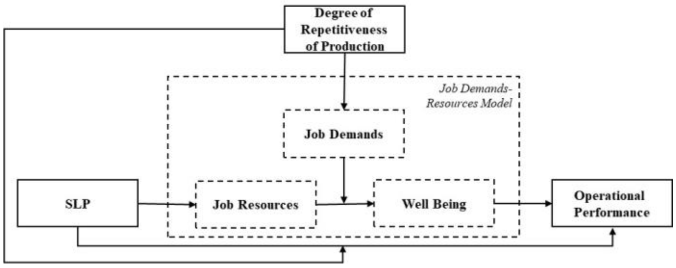

Figure 1 Hypothesized model

Our second argument is related to the levels of work-in-process (WIP) inventory that differ among systems with different degree of repetitiveness.
In general, within non-repetitive production environments following MTO or ETO strategy, a large amount WIP is available in order to decouple various production processes, whereas in more repetitive production systems WIP inventories are low to optimize production flow (White & Prybutok, 2001). Going back to one of the most famous Ohno's metaphor, the level of stocks of a system represents the sea level and only by reducing this level it is possible to make rocks (*muda*) visible and remove them (Lander & Liker, 2007). In accordance with this analogy, in high repetitive production systems such as assembly lines generally characterized by less between-processes inventories in comparison to job shops, the problems are more visible and more likely to be faced and solved through effective kaizen activities.

3. Methodology

Data collection

To test our hypothesis, we used a database including 199 plants in 8 countries, from the fourth round of the High Performance Manufacturing Project (Schroeder & Flynn, 2002). Plants operates in machinery (SIC code: 35), electronics (SIC code: 36) and transportation components (SIC code: 37) industries.

Measures

SLP have been measured using multi-item scales based on existing literature and previously validated measures (Table 1). For each item, respondents indicated their level of agreement on a five- point Likert scale, from 1 (strongly disagree) to 5 (strongly agree).

Specifically, continuous improvement has been measured by three items based on Liu et al. (2006), reflecting the effort organization put in constantly improve existing products and processes. Employee suggestions has been measured by three items adapted from Zeng et al. (2015) capturing the extent employees are encouraged to make suggestions, how much these suggestion are taken seriously and utilized in the plant. Finally, small group-problem-solving has been measured with a four item scale based on Zeng et al. (2015) that catch the extent the plant uses teams to solve problems.

Similar to other studies (Chi Anh & Matsui, 2011) operational performance has been assessed through different items evaluating various facets of operational performances such as efficiency, quality, delivery, flexibility and employee relations.
Respondents were asked to rate how their plant performs on that specific aspect in comparison to its competitors in its industry, on a 5-point Likert scale from poor (1) to superior (5). Quality has been measured according with Liu et al. (2009), through two items: conformance to product specifications, product capability and performance. Efficiency has been captured through three items (Bortolotti, Danese & Romano, 2013): unit cost of manufacturing, inventory turnover, cycle time. Regarding delivery and flexibility we used 2 items each: on-time delivery and fast delivery for delivery

performance and flexibility to change product mix and flexibility to change volume for flexibility performances (McKone-Sweet & Lee, 2009). In addition, we included a measure of the quality of employee relations, given that respect for employees is generally considered as a central element in the Toyota Production System and lean in general (Womack, Jones & Roos, 1990; Sugimori *et al.*, 1977). A single perceptual item measuring how the plant performs in terms of employee relations has been included.

Table 1 Measurement Items and CFA results for the measurement model

Measurement Item	Std loading
Continuous Improvement (α=0.68; CR=0.77; AVE=0.53)	
We strive to continually improve all aspects of products and processes, rather than taking a static approach.	0,67
Continuous improvement makes our performance a moving target, which is difficult for competitors to attack.	0,61
Our organization is not a static entity, but engages in dynamically changing itself to better serve its customers	0,60
Employee suggestions (α=0.79; CR=0.86; AVE=0.61)	
Management takes all product and process improvement suggestions seriously.	0,64
We are encouraged to make suggestions for improving performance at this plant.	0,65
Management tells us why our suggestions are implemented or not used.	0,66
Many useful suggestions are implemented at this plant.	0,78
Small group Problem-solving (α=0.74; CR=0.84; AVE=0.58)	
During problem-solving sessions, we make an effort to get all team members' opinions and ideas before making a decision.	0,51
Our plant forms teams to solve problems.	0,74
In the past three years, many problems have been solved through small group sessions.	0,64
Problem-solving teams have helped improve manufacturing processes at this plant.	0,76
Efficiency Performances (α=0.68; CR=0.68; AVE=0.43)	
Unit cost of manufacturing	0,42
Inventory turnover	0,72
Cycle time (from raw materials to delivery)	0,74
Quality Performances (α=0.73; CR=0.67; AVE=0.51)	
Conformance to product specifications	0,72
Product capability and performance	0,69
Delivery Performances (α=0.69; CR=0.74; AVE=0.59)	
On time delivery performance	0,68
Fast delivery	0,83
Flexibility Performances (α=0.71; CR=0.73; AVE=0.58)	
Flexibility to change product mix	0,72
Flexibility to change volume	0,79
Employee relations performances (-)	
Employee relations	-

To measure the degree of repetitiveness of the production system, we asked process engineers to indicate which percentage of the production volume is manufactured in each of production configurations (job shop, manufacturing cells, mixed model lines, assembly lines/flow lines). Similarly to other studies (Bortolotti, Danese & Romano, 2013; Sandrin, Trentin & Forza, 2018; McKone-Sweet & Lee, 2009), we create a variable representing the degree of repetitive production as the weighted average with a specific weight of each type of category, from job shop (weight 1) to assembly line/flow line (weight 4).

Measurement model

We performed maximum likelihood confirmatory factor analysis (CFA) using AMOS 23 with all our variables in a single measurement model, including company size (measured by natural logarithm of the number of plant employees) as a control variable. In order to control for the country and industry effects on operational performance, coherently with other studies (Sandrin, Trentin & Forza, 2018; Liu, Shah & Schroeder, 2006), we conducted CFA and SEM analysis on standardized residuals obtained from a linear, ordinary least square regression on every single performance with country and industry dummy variables as only independent variables in the model.

We contemporary assessed model fit and factor loading in order to obtain a measurement model that satisfies goodness-of-fit indices and convergent validity in terms of significance and magnitude of items factor loadings (>0.50). Items strongly undermining model fit or not exceeding 0.5 factor loading threshold were progressively removed, cross- checking also for an acceptable content validity of remaining items.

The final CFA model shows adequate fit ($\chi^2 = 253; \chi^2/df = 1.338$; CFI=0.95; IFI = 0.954; RMSEA=0.041; SRMR=0.055).

All the remaining items load on the specified latent construct with factor loadings significant at p-value <0.001 and bigger than 0.5, except for cost of manufacturing. Since this is a fundamental item in terms of content validity for efficiency performance construct and it has been largely utilized in previous literature as a measure of efficiency and operational performance (Bortolotti, Danese & Romano, 2013; Liu, McKone-Sweet & Shah, 2009), we decided to keep the item in the model, given also the fact that the loading of 0.42 is close to 0.5 and it is significant at a 0.001 level.

Discriminant validity has been assessed through Bagozzi et al method (1991) providing evidence that the constructs are discriminated from each other.

Reliability has been assessed through Cronbach alpha, composite reliability (CR) and averaged variance extracted (AVE). All reliabilities are close or even higher 0.7, but beyond the limit of 0.6 suggested by Bagozzi and Yi (1988). AVE indicates a good reliability for all constructs except for Efficiency performance (0.42). However, a minimum value of 0.4 it has been considered acceptable in previous OM literature (e.g. Murat Kristal, Huang & Schroeder, 2010; Sandrin, Trentin & Forza, 2018)

Results

In order to triangulate the results, we test our hypothesis using two different procedures. First, we have performed a hierarchical ordinary least square regression with an interaction term, in SPSS 24. Secondly, we have tested the moderation through Ping procedure (Ping, 1995) with moderated structural equation modelling (MSEM).

Before proceeding with tests however, given the general structure of our hypothesis in terms of SLP and operational performance, we decided to aggregate our first order constructs in two second order constructs: soft lean practices (SLP) and operational performance. This choice assumes that both operational performance and SLP can be represented as second order factors, each containing related but distinct first order constructs. The second order construct of SLP shows acceptable fit ($\chi^2 = 77.88\,; \chi^2/df = 1.899$; CFI=0.949; IFI = 0.95; RMSEA=0.067; SRMR=0.050).

Operational performance defined as a second order construct has acceptable fit ($\chi^2 = 50.61\,; \chi^2/df = 1.633$; CFI=0.967; IFI = 0.968; RMSEA=0.057; SRMR=0.0463).

All the first order constructs load significantly on the constrained second-order construct and are >0.5. Finally, after second order construct validation, we have proceeded through parcelling all first order constructs belonging to SLP and operational performance in order to simplify the overall model and avoid over-specification. Each first order construct has been redefined as a single indicator obtained through the mean of the items (Bortolotti *et al.*, 2015; Sila, 2007; Sandrin, Trentin & Forza, 2018).

Hierarchical regression results

We used moderated hierarchical multiple regression in SPSS 24, controlling for country, industry and size. Results are reported in Table 2.

Table 2 Hierarchical regression analysis (Dependent variable: Operational Performance)
** p-value < 0.05 level, ** p-value < 0.01 level, *** p-value < 0.001 level*

Predictors and Regression Diagnostics	Control variables		Mai effect		Interaction	
	MODEL 0 coeff.		MODEL 1 coeff.		MODEL 2 coeff.	
	Unstd.	Std.	Unstd.	Std.	Unstd.	Std.
Constant	3,447***	0***	3,578***	0***	3,58***	0***
Germany	0,09	0,062	0,081	0,057	0,09	0,063
Spain	0,21	0,142	0,204	0,136	0,216	0,144
Israel	0,23	0,159	0,269	0,182	0,258	0,175
Japan	0,385*	0,243*	0,397**	0,25**	0,391**	0,247**

China	0,16	0,118	0,149	0,108	0,184	0,133
South Korea	0,00	0,003	0,021	0,014	0,025	0,017
United Kingdom	0,484**	0,241**	0,508**	0,253**	0,539***	0,268***
Industry 1	-0,01	-0,008	-0,005	-0,005	-0,016	-0,016
Industry 2	0,06	0,055	0,012	0,011	0,012	0,011
ln (num of employees)	0,01	0,028	-0,008	-0,017	-0,01	-0,023
Deg. of repetitiveness (REP)	-	-	0,002	0,076	0,004	0,138
Soft Lean practices (SLP)	-	-	0,214**	0,225**	0,226**	0,237**
REP x SLP	-	-	-	-	0,008*	0,166*
R^2	0,092		0,146		0,169	
ΔR^2	0,092		0,054		0,023	
F- value of ΔR^2	1,906*		2,648**		2,891***	

Structural equation modelling results

To test our hypothesis through MSEM, we have adopted Ping's (1995) two step procedure. Furthermore, we have mean-centered interaction variables included in the model. The first step of Ping approach consists in testing the direct effect of SLP and degree of repetitiveness of production on operational performance. Then, first step estimated parameters are used as input in the second step, where the interaction single item construct, calculated by multiplying the sum of the items composing SLP by degree of repetitive production item, is added to the model. Figure 2 shows the results for the second-step model. Goodness of fit indices show an optimal fit of the model to the data ($\chi^2 = 40.24\,; p - value = 0.371\,; \chi^2/df = 1.059$; CFI=0.996; IFI = 0.996; RMSEA=0.017; SRMR=0.0403).

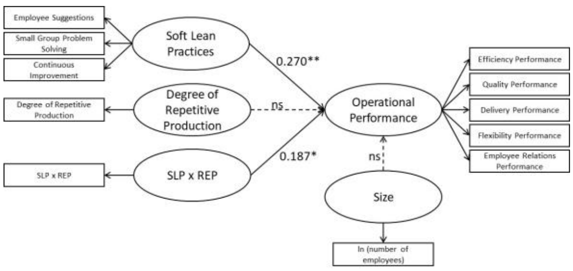

*Figure 2 Moderation results. Standardized regression weights are reported. * p-value < 0.05 level, ** p-value < 0.01 level*

In hierarchical regression and MSEM tests, both SLP and the interaction term between SLP and degree of repetitiveness of production are significantly related to operational performance supporting our two hypotheses.

Discussion

The results provide several implications. Firstly, they confirm the literature on the positive impact of SLP on operational performances.

Secondly, we provide empirical evidence that the impact of SLP practices on operational performances is not the same in all the contexts, since the degree of repetitiveness of production moderates positively this relationship.

Looking back in early lean literature, considerations reinforcing our results can be found. Anecdotal evidence reports of Taiichi Ohno's incursions in the shop floor looking for resources to remove, to stimulate continuous improvement (Schonberger, 1982; Conti & Gill, 1998).

From a practical point of view, we claim that in more repetitive systems workers tend to be more effective in providing feasible solutions to real production problems because of the lack of WIP that hinder process visibility and protect them against disruptive events and because they are pushed by high demands they experience over the day.

These suggestions and the problem-solving activities are concurrently improving working conditions by directly involving workers in job design and increasing operational performances, since only suggestions coherent with the company continuous improvement approach are implemented.

This research is subject to generic survey limitations. We used a cross-sectional database of medium and large enterprises in specific industries that could limit the findings generalisability. Future studies should include other industries and/or small companies to validate the data.

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