Exploring the role of human factors in lean management

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Abstract

Purpose – Although lean popularity is rapidly growing, its implementation is far from problem-free and companies may experience difficulties in sustaining long-term success. On this premises, the purpose of this paper is to understand to what extent human factors, affected by the implementation of both hard (defined as technical and analytical tools) and soft (concerning people and relations) lean practices, play a key role in achieving long-term superior performance.

Design/methodology/approach – The analysis of the relationships between lean practices implementation, human factors and operational performance is carried out in a single exploratory case study. A retrospective approach is adopted to trace the changes of human and operational performance before, during and after the introduction of lean management (LM) implementation. In particular, a mixed method concurrent design merging results of a qualitative analysis with data collected from a survey is selected to provide a more realistic benefit in the exploration of the proposed research questions.

Findings – The results show a short-term direct relationship between the implementation of lean practices (hard and soft) and physical work environment and job characteristics, directly connected to operational outcome. In the long term, operational performance is influenced by employee behaviour outcome and conditioned by physical work environment and job characteristics with the mediating effect of individual characteristics.

Practical implications – The proposed model supports the building of a roadmap for LM implementation, taking into account the role of the human factors to achieve superior operational performance. Moreover, it helps managers to implement a monitoring system to check how social and technical components of a LM system evolve over time. Finally, it supports the definition of specific training programs, tailored for specific workers' types.

Originality/value – This paper extends theory in LM, highlighting how hard and soft lean practices have to interact to enable a successful LM implementation.

Keywords Human factors, Job characteristics, Lean practices, Lean management, Employee behaviour outcome, Physical work environment characteristics

Paper type Research paper

1. Introduction

The philosophy and practices associated with lean management (LM) have been around for many years, and have been applied in a number of settings (Netland and Powell, 2016) for the systematic elimination of waste (*muda*), i.e. everything that does not contribute to the added value of a product, under the perspective of customer's needs and requirements (Womack *et al.*, 1990). The philosophy underlying an LM approach, named lean thinking, relies on five main principles (Womack and Jones, 1996):

(1) Define what values for the customer.
(2) Identify the value stream.
(3) Make the value flow.
(4) Customer "pulls" the value stream.
(5) Strive for perfection.

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LM is considered by managers as a means to improve multiple dimensions of operational performance, including production cost reduction and speed, quality, dependability and flexibility improvement (Belekoukias *et al.*, 2014).

While there are many lean success stories, a number of real cases failed to achieve superior performance by applying a lean approach (Ballé, 2005). Several scholars discussed the causes of this lack of success, many of which are indicative of problems that arise in the human element during a changeover to lean (Sawhney and Chason, 2005; Veech, 2004). The application of lean tools without a simultaneous strive for a lean mind is not enough for a conventional organisation to become a lean firm (Liker, 2004): a balanced and holistic system view that emphasises the role of persons delivering value to customers in improving corporate performance is needed (Bicheno, 2004). Therefore, a focus on human factors involvement and motivation is imperative when implementing a lean approach:

> Focus on the people and the results will follow. Focus on the results, and you'll have the same troubles as everyone else – poor follow-up, lack of interest, no ownership of improvements, diminishing productivity (Mann, 2014).

Extant literature concerning the role of human factors in LM applications is fragmented, with partial and conflicting claims emerging from operations management (OM) researchers, ergonomics scholars, sociologists and psychologists (de Treville and Antonakis, 2006; Hasle *et al.*, 2012). Previous studies recognised the importance of the human aspect of an LM system (Agarwal *et al.*, 2013; Arezes *et al.*, 2015), considering both the management and the workforce (Sawhney and Chason, 2005): people are, at the same time, at the centre, the source and the main drivers of lean applications. However, while LM proponents argue that lean workers show an intrinsically motivated behaviour and appear more productive, leading to improved operational performance, LM opponents suggest that workers operate in limiting and alienating conditions that create a dependent and deskilled workforce (de Treville and Antonakis, 2006). Only few studies empirically support such hypotheses (Longoni *et al.*, 2013; Farris *et al.*, 2009; Saurin and Ferreira, 2009; Parker, 2003; Jun *et al.*, 2006), with a mixture of both positive and negative results. Therefore, the debate about relationships between LM implantation and human factor elements is still open and require further analyses.

Moreover, most of the studies focusing on the impact of LM implementation on operational performance are constrained to facets of lean, often limited to specific technical tools (Cua *et al.*, 2001), whereas human aspects of lean implementation are often neglected or partially considered (Yang *et al.*, 2012).

Finally, as indicated in literature, the introduction of lean approaches often does not provide companies those long-term operational benefits promised in the literature (Bhasin, 2012; McLean *et al.*, 2015). As LM is a philosophy that requires long-term commitment to achieve better results (Bhasin and Burcher, 2006), considering the temporal progression of a lean implementation emerges as essential to sustain operational performances in the long term. However, researchers are restricting their studies to short-term data instead of longitudinal data collection (Jasti and Kodali, 2014). Therefore, to fully understand the LM system, researchers have to give equal priority to the longitudinal data collection method.

In summary, due to the lack of appropriate models encompassing all the dimensions related to the role of human factors in LM applications considering a longitudinal viewpoint, two decades of discussion have yielded little progress. Thus, a comprehensive theoretical model is necessary to analyse the complex network of variables both "acting upon" and "experienced by" the employees (Genaidy and Karwowski, 2003). Such variables should include physical, cognitive, organisational, economic, technological and social parameters,

and must be analysed and examined with respect to work outcomes to uncover the best human performance practices.

In such a context, this paper aims at contributing to filling this gap by exploring the effects of lean practice implementation on human-related factors (physical and psychological human aspects), as well as the effects of human-related factors on operational performance in the short and long term, adopting a retrospective perspective, considering both worker and management standpoints.

The paper is organised as follows: Section 2 presents the theoretical background of the study and the research conceptual framework. In Section 3, the research methodology is described and the empirical study carried out in a manufacturing company is presented. In Section 4, research findings and implications are presented. Finally, the last section closes the paper with the most relevant conclusions and future research directions.

2. Theoretical background and research framework

As argued by Shah and Ward (2007), LM is "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability". It is a multi-dimensional approach that encompasses a wide variety of management practices, working synergistically and mutually reinforcing. In particular, LM practices have been defined by the same authors (Shah and Ward, 2003) as "tools for creating a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste". Despite the wide range of LM practices available to companies for LM implementation, the selection of appropriate lean tools, together with their applicability, incorporation and acceptance within operations remains the major problem for many companies (Herron and Braiden, 2006). Moreover, as reviewed by Larteb *et al.* (2015), lean conceptualisation varies considerably among studies in terms of practices considered. Nevertheless, a recognised approach in the study of LM implementation distinguished practices between hard and soft (Fotopoulos and Psomas, 2009). As defined by Bortolotti *et al.* (2015), hard practices refer to "technical and analytical tools introduced to improve production systems" (i.e. statistical process control or Kanban), whereas soft practices are related to "principles, managerial concepts, people, and relations" (i.e. continuous improvement, top management leadership and customer and supplier involvement). In Table I, the main hard and soft LM practices are reported.

Despite the implementation of hard practices has been demonstrated being a strong predictor of lean contribution to operational performance improvements, soft practices are essential for obtaining greater outcomes (Bortolotti *et al.*, 2015): the efficacy of hard practices is magnified when soft practices are simultaneously and systematically applied (Rodriguez *et al.*, 2016).

Hard practices	Soft practices
Set-up time reduction	Small group problem solving
Just-in-time delivery by suppliers	Training employees
Equipment layout for continuous flow	Top management leadership
Kanban	Supplier partnership
Statistical process control	Customer involvement
Autonomous maintenance	Continuous improvement

Source: Bortolotti *et al.* (2015)

Table I.
Lean hard and soft practices

According to the socio-technical system theory (Hasle *et al.*, 2012; Hallgren and Olhager, 2009), lean will produce the greatest increases in performance when both social and technical components are addressed. To guide the investigation reported in this paper, ergonomics literature has been reviewed and used to build the research conceptual model. In particular, the broad definition of ergonomics proposed by the International Ergonomics Association (IEA) has been used:

> Ergonomics (or human factors) is [. . .] concerned with the understanding of interactions among humans and other elements of a system, [. . .] in order to optimize human well-being and overall system performance (IEA, 2000).

This definition has several implications:

- Ergonomics has both social and economic objectives.
- Ergonomics takes into consideration both physical and psychological human aspects.
- Ergonomics looks for improvements in both technical and organisational domains (Dul and Neumann, 2009).

Therefore, the implication of lean on physical and psychosocial work environment, as well as on performance improvement, is hereafter described and modelled into a research conceptual model that will guide the empirical investigation.

2.1 Physical work environment characteristics

Physical features of a workplace environment, defined as the characteristics of the physical space in which work is done (Vischer, 2007) and describing all material objects and stimuli that employees interact with in their working lives (Elsbach and Pratt, 2007), have been proved to influence health and safety, comfort and job satisfaction of the people within it (Dawal and Taha, 2006; Kahya, 2007; Nazari *et al.*, 2012; Dianat *et al.*, 2016) due to the continuous and dynamic interaction between the employees and their surrounding environment (Parsons, 2000). Salient factors within the physical work environment that may affect employees can be divided into several broad areas (Elnaga, 2013; McCoy, 2002; Vischer, 2007):

- *Workplace safety*. Lean tools are argued to positively affect workplace safety, in particular by implementing 5S methodology, visual management tools, poka-yoke solutions, standard work approaches (Kamishibai) and problem-solving methods (Hafey, 2009). A safe workplace can reduce workers' stress and fatigue and increase their productivity. Reducing injuries means reducing operating costs, improving operator's commitment and enhancing corporate's image (Aqlan *et al.*, 2013).
- *Workplace spatial arrangements* (layout). Lean employees work in a U-shaped cell layout, with all machines necessary to produce a product or a family of products (Aase *et al.*, 2004). The U-shaped layout is able to decrease work monotony (Miltenburg, 2001), as team members could adopt different and flexible work patterns or cell operating nodes (Arezes *et al.*, 2015).
- *Workplace cleanliness*. Workplace cleanliness is created by removing waste from the work area (Hutchins, 2007). In particular, Seiso (second S of the 5S methodology) requires cleanliness in the workplace (Gapp *et al.*, 2008), which is everyone's responsibility. A clean environment has a positive psychological effect on human beings. People will be happy to work in a clean environment and their motivation may be raised. If this happens, productivity will increase as a result (Makhbul, 2013).

Moreover, some products may require clean environments to uphold product quality. If contamination happens due to uncleanliness in the workplace, products will be rejected or reworked with a negative effect on productivity.

- *Ambient properties* (i.e. noise, temperature, air quality and vibration). In work areas in which thermal comfort, appropriate illumination, pleasant sound and comfortable air quality are enhanced, work performance may be encouraged (McCoy, 2002). On the contrary, several studies have demonstrated that inappropriate ambient properties are environmental stressors, with a negative effect on worker morale, productivity and health (Vischer, 2007). In literature, no studies on the effect of LM on ambient properties have been found.
- *Functional comfort*. Functional comfort addresses how effective the workplace is in helping users perform their tasks, being a tool to help get work done. In a lean context, the workplace is explicitly designed to minimise unnecessary and risky workers' motions (Womack and Jones, 1996), in accordance with a human-centred system design approach (Gill, 2012). When the workstation is designed from an operator's perspective, all the material and tools used during a work shift should be placed inside the comfort zone to aid the operator to work as efficiently as possible, aiming at "working smarter, not harder" (Eswaramoorthi *et al.*, 2010). To reduce unnecessary wear on the human body, ensuring good ergonomics, and generate increased productivity and safety, materials and tools most frequently used should be placed as close as possible to the operator, as prescribed by Seiri and Seiton practices included in the 5S methodology (Finnsgård *et al.*, 2011; Gapp *et al.*, 2008).

2.2 Job characteristics

According to the job characteristics model introduced in 1976 by Hackman and Oldham, and refined by Parker and Wall (1998), a job is characterised by five core dimensions:

(1) *Skill variety* is defined as "the degree to which a job requires a variety of different activities in carrying out the work, which involves the use of a number of different skills and talents of the person" (Hackman and Oldham, 1976). In a lean context, lean practices implementation results in an increase in skill variety if workers are involved in problem-solving activities, training programs and job rotating policies (de Treville and Antonakis, 2006).

(2) *Task identity* is defined as "the degree to which the job requires completion of a "whole" and identifiable piece of work; that is, doing a job from beginning to end with a visible outcome" (Hackman and Oldham, 1976). As argued by de Treville and Antonakis (2006), LM implementation is positively related to task identity if the worker is aware of his/her tasks' contribution to the whole product manufacturing process. On the contrary, a flexible allocation of tasks to workers and the removal of boundaries between functions, as indicated by a lean approach, cause a decrease in task identity, preventing the workers from producing a whole identifiable piece of work (Mehta and Shah, 2005).

(3) *Task significance*, considered "the degree to which the job has a substantial impact on the lives or work of other people, whether in the immediate organisation or in the internal environment" (Hackman and Oldham, 1976), is reduced in organisational environment characterised by a low degree of technical uncertainty (i.e. of the amount of information processing and decision making required when executing a task) (Mehta and Shah, 2005).

(4) *Autonomy* is "the degree to which the job provides substantial freedom, independence, and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out" (Hackman and Oldham, 1976). While several scholars (de Treville and Antonakis, 2006; Genaidy and Karwowski, 2003) stated that autonomy is positively affected by LM implementation in situations where workers actively participate in the decision-making process, other studies (Parker, 2003; Hasle *et al.*, 2012; Mehta and Shah, 2005) found strong evidence of a negative effect of lean LM on job autonomy, as most of the workers follow imposed rigid work patterns, which tend to limit their freedom to decide on their work.

(5) *Feedback*, defined as "the degree to which carrying out the work activities required by the job results in the individual obtaining direct and clear information about the effectiveness of his/her performance" (Hackman and Oldham, 1976), is improved by LM applications (de Treville and Antonakis, 2006). Feedback in LM allows prompt response to deviation from the target and production improvement, as well as increase in accountability (Mehta and Shah, 2005).

2.3 Employee behaviour outcome

Employee behaviour was formalised in 80s by introducing the individual behaviour (IB) concept, defined as the attitude and actions or deeds of an individual working in an organization (Arnett, 1988). IB is affected by three factors, namely, job satisfaction, commitment and job stress, which represent the main components of the employees' affective attitude construct (Rodwell *et al.*, 1998). Usually, employees develop different attitudes towards their work depending on their working environment and job characteristics (Monge and Poole, 2008). As reviewed by Parker (2003), a mixture of both positive and negative consequences of LM implementation on employee behaviour outcomes is reported in the literature:

- *Job satisfaction* is defined as the "extent of satisfaction an employee extracts while performing the assigned task" (Muchinsky, 2006). Job satisfaction relates to job characteristics such as monotony, type of work and control over the work, as well as the working environment. Both negative and positive consequences have been described in several studies (Lipińska-Grobelny and Papieska, 2012), or at least a mixture of both negative and positive results (Jackson and Mullarkey, 2000). According to Rodriguez *et al.* (2016), in a lean environment, employee job satisfaction can be improved when human resource practices (e.g. teamwork, praise for higher performance, regular feedback, training, focus on customer value, empowerment and better understanding of individual tasks and the customers' needs) are implemented.
- *Job commitment* is the "extent to which an employee feels attachment or trustworthiness towards an organization" (Muchinsky, 2006). In the literature review of lean production from 1999 through 2006 conducted by Hasle *et al.* (2012), studies have reported both negative and positive effects of lean production on organisational commitment.
- *Job stress* is a feeling of discomfort related to factors such as time deadlines and anxiety, which may lead to degraded performance (Parker and DeCotiis, 1983). Job stress is one of the most cited negative effects of LM on workers' outcome, especially

when considering just in time methods (Koukoulaki, 2014; Conti *et al.*, 2006; Hasle *et al.*, 2012).

2.4 Operational performance

As extensively reviewed by Belekoukias *et al.* (2014), extant literature attributes a wide range of operational benefits to the implementation of LM philosophy and practices, including production cost reduction and speed, quality, dependability and flexibility improvement. In particular, when measuring the direct impact of lean practices on operational performance, different authors have tried to connect and reflect the combined effect of these practices into one indicator (Bayou and de Korvin, 2008), now popularly known as "leanness". It includes (Belekoukias *et al.*, 2014) quality, speed, dependability, flexibility and cost.

Moreover, several disagreeing studies have recently been published about the existence and strength of the relationship between employee behaviour outcome and operational performance in a LM context. Bowling (2007) suggested that this relationship is spurious. In contrast, a number of scholars (Riketta, 2008; Mehta and Shah, 2005; de Treville and Antonakis, 2006) proposed that a significant relationship between these two variables does in fact exist. On the basis of these mixed results, additional examination of the relationship between employee behaviour outcome and performance is necessary (Rodriguez *et al.*, 2016).

2.5 Building a complete perspective

As previously argued, the inclusion of both technical and human elements in an LM approach produces the greatest improvements in performance. However, the theoretical background earlier presented demonstrates that existing literature provides limited evidence on how the two elements interact and how they are interconnected. This research addresses this gap by exploring the impact of hard and soft lean practices on job and physical work environment characteristics and how these characteristics influence the employee behaviour outcome, intended as the direct element acting upon the operational performance of the system. Specifically, this paper aims to answer the following main research question:

RQ. How do lean technical and human elements influence operational performance?

The initial conceptual model that underpins this research is depicted in Figure 1.

Table II provides definitions for the six constructs included in the conceptual model, as well as information on their operationalisation.

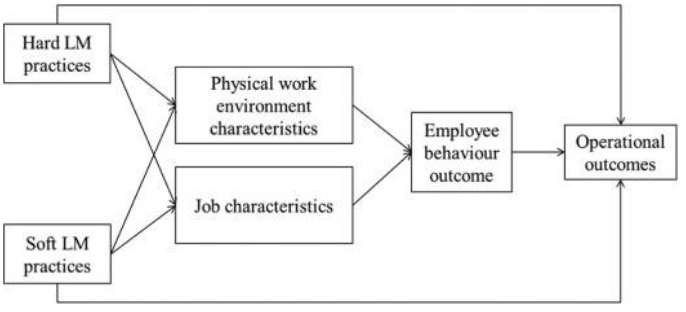

Figure 1.
Research conceptual model

Construct	Measurement variables	Description	References
Hard lean management practices	Set-up time reduction	Practices to minimise and standardise set-up tasks that should be separated into internal and external	Bortolotti *et al.* (2015) Marodin *et al.* (2015) Shah and Ward (2007)
	Just-in-time delivery by suppliers	Integration of vendors into production in terms of using Kanban containers, making frequent or JIT delivery and quality certification	
	Equipment layout for continuous flow	Use of manufacturing cells, elimination of forklifts and long conveyers and use of smaller equipment designed for flexible floor layout, to enable and ease the continuous flow of products	
	Kanban	Implementation of the Kanban system	
	Statistical process control	Methods for understanding, monitoring and improving process performance over time	
	Autonomous maintenance	Tools to carry out routine maintenance on all equipment (e.g. cleanliness, lubrication and small repairs) following standardized procedures. Operators are responsible for maintaining their own equipment	
Soft lean management practices	Small group problem solving	Employees are organized in work teams and involved in problem solving groups	
	Training employees	Formal job design, job rotation and cross-functional training programs	
	Top management leadership	Top managers act as role models to exemplify the desired behaviour for lean implementation, taking initiatives in defining and communicating the vision of change and setting goals	
	Supplier partnership	Long-term relationship between buyer and supplier based on trust, open communication and close interaction	
	Customer involvement	Involvement of the customer in the definition of value	
	Continuous improvement	Formal continuous improvement programs	
Physical work environment characteristics	Safety	Degree of work-related risks	Elnaga, 2013, Hedge (2000), McCoy (2002), Vischer (2007)
	Spatial arrangements	Workplace layout	
	Cleanliness	Degree of workplace cleanliness	
	Ambient properties	Degree of noise, temperature, air quality and vibration in the workplace	
	Functional comfort	Effectiveness of the workplace in helping users perform their tasks	

Table II.
Initial conceptual model – components

(*continued*)

Construct	Measurement variables	Description	References
Job characteristics	Skill variety	Degree to which a job requires a variety of different activities in carrying out the work	Hackman and Oldham (1976)
	Task identity	Degree to which the job requires completion of a "whole" and identifiable piece of work	
	Task significance	Degree to which the job has a substantial impact on the lives or work of other people	
	Autonomy	Degree to which the job provides substantial freedom, independence and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out	
	Feedback	Degree to which carrying out the work activities required by the job results in the individual obtaining direct and clear information about the effectiveness of his/her performance	
Employee behaviour outcome	Job satisfaction	Extent of satisfaction an employee extracts while performing the assigned task	Rodwell *et al.* (1998)
	Job commitment	Extent to which an employee feels attachment or trustworthiness towards an organization	
	Job stress	Feeling of discomfort related to factors such as time deadlines and anxiety	
Operational performance	Quality	Conformance to specifications	Belekoukias *et al.* (2014)
	Speed	Delivery speed	
	Dependability	On-time delivery performance	
	Flexibility	Flexibility to change product mix and volume	
	Cost	Unit manufacturing cost	

Table II.

3. Research methodology

This paper is based on an in-depth single exploratory case study conducted in Company Alpha, a medium manufacturer of draft dispensing equipment for beer, wine, water and other soft drinks. The company has recently expanded its production plants and has introduced a multi-year lean manufacturing project to continuously advance its production efficiency, drive out waste and increase the productivity of the whole supply chain.

Although multiple case studies are considered to build more robust theory (Yin, 2009) due to their potential for triangulation, single case studies may be useful for longitudinal research (Voss *et al.*, 2002), to determine patterns efficiently. Indeed, by using longitudinal studies, it is possible for researchers to learn more about cause and effect relationships and make connections in a clearer manner.

The present study relies on a mixed methods concurrent design (Driscoll *et al.*, 2007). Mixed methods research is formally defined as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Johnson and Onwuegbuzie, 2004). Qualitative methods included open-ended interview, observation, participant observation and analysis of responses to open-ended items on a survey questionnaire (Kaplan and Duchon, 1988). Quantitative methods were used to collect and analyse data from survey questionnaires.

Compared to mono-method research, mixed methods research frequently results in superior research due to its methodological pluralism or eclecticism (Johnson and Onwuegbuzie, 2004) and provide pragmatic advantages when exploring complex research questions (Driscoll *et al.*, 2007). The qualitative data provide a deep understanding of survey responses, and statistical analysis can provide a detailed assessment of patterns of responses. Moreover, a retrospective approach was adopted to trace the changes in the LM socio-technical system and in its operational performance. In particular, three time periods were identified:

(1) before the introduction of LM;

(2) first phase of LM implementation (2011-2013); and

(3) second phase of LM implementation (2014-2016).

Only employees who experience all the three phases were included in the sample.

In particular, based on the research conceptual model previously presented, two research protocols were developed including both open-ended and scaled-response questions. Scaled-response questions were answered on a five-point Likert-scale. The first research protocol, covering the hard LM practices and soft LM practices, as well as the operational performance constructs, was addressed to top managers to analyse the implementation level of LM practices and how it varied throughout the years, after the implementation of the first LM project. The second research protocol was addressed to workers to assess the changes introduced by LM activities in job and physical work environment characteristics and employee behaviour outcome. In the past, a limited number of studies considered both the managerial and worker perspective (Genaidy and Karwowski, 2003). In both protocols, questions about respondent's general information (years of experience in Alpha, age, gender, education, main activity, type of contract and participation in lean practice implementation) were introduced.

Based on responses from Alpha's employees at a single lean site, the authors explored the relationships between the technical and human elements of a LM system and their impacts on operational performance.

4. Data analysis and results

A logic model approach was used to analyse the data, consisting of "matching empirically observed events to theoretically predicted events" (Yin, 2009). The research conceptual model presented in Figure 1 represents a preliminary theoretical expectation of how the implementation of lean practices affects job and physical work environment characteristics, how these characteristics influence employee behaviour outcome and how the employee behaviour outcome affects operational performance. During the analysis, data were compared to the research conceptual model, through pattern matching investigation, also exploring rival or alternative models (Yin, 2009). The final model represents new theory that builds on both the initial research conceptual model and alternative explanations suggested by data analysis.

4.1 Demographic details

A total of 81 operational workers and five managers (representing the totality of Alpha's employees) were interviewed. Table III presents demographic and job characteristics of the study participants. All study participants had a normal 8-h work shift. The age of participants ranged between 20 and 58 years, of which about half of them (n = 42; 49 per cent) were 35-47 years old. The job experience of the respondents

Demographic and job characteristics	(%)
Gender	
Male	76
Female	24
Age	
<35	30
Between 35 and 45	39
>45	31
Years of experience in Alpha	
<6	38
Between 6 and 10	23
>10	39
Education	
Primary school	34
High school	48
University	18
Main activity/Department	
Production	52
Logistics	11
Other departments	37
Type of contract	
Long term	79
Short term	21
Lean experience	
Yes	52
No	48

Table III. Respondents' characteristics

ranged between 6 and 30 years. A total of 34 per cent of the participant had primary school education, whereas 48 per cent had secondary education and 18 per cent had university degrees.

4.2 Statistical data analysis

First, for each item, responses were analysed using frequency distribution analysis, mean and median values. Since all the items were evaluated using an ordinal scale (1-5 Likert scale) and the analysis referred to the comparison of repeated measurements on a single sample overtime, a Wilcoxon signed rank test (with a p-value of 0,05) was identified as the right test to verify statistically differences of the achieved values between different periods (Table IV). Afterwards, achieved results combined with findings from interviews were used to support the general discussion, as presented in the following sections.

4.3 Lean manufacturing implementation in Alpha

Alpha is an owned family business company specialized in supplying complete dispensing equipment, such as towers, cooling units, accessories and spare parts for beer, wine, soft drink and water. Thanks to its management dedication in investing in innovation and flexibility, the company is present worldwide, and serves the major iconic brands in the beverage field in more than 110 countries.

Constructs and measurement variables	Before lean implementation vs first phase		First phase vs second phase	
	Z	Sign.	*Z*	Sign.
Hard practices				
Autonomous maintenance	n.a.	n.a.	−2.762	0.006**
Equipment layout for continuous flow	n.a.	n.a.	−3.207	0.001**
Just-in-time delivery supply	n.a.	n.a.	−2.271	0.023**
Kanban	n.a.	n.a.	−3.535	0.000**
Set-up time reduction	n.a.	n.a.	−2.449	0.014**
Statistical process control	n.a.	n.a.	−4.630	0.000**
Soft practices				
Continuous improvement	n.a.	n.a.	−4.802	0.000**
Customer involvement	n.a.	n.a.	−2.121	0.034**
Small group problem-solving	n.a.	n.a.	−4.001	0.000**
Supplier partnership	n.a.	n.a.	−2.640	0.008**
Top management leadership	n.a.	n.a.	−3.493	0.000**
Training employees	n.a.	n.a.	−4.669	0.000**
Physical work environment characteristics				
Functional comfort	2.630	0.009**	−4.252	0.000**
Workplace spatial arrangements (layout)	−1.537	0.124*	−4.534	0.000**
Workplace cleanliness	−2.846	0.004**	−4.127	0.000**
Ambient properties	−1.523	0.128*	−5.035	0.000**
Workplace safety	−3.920	0.000**	−3.674	0.000**
Job characteristics				
Autonomy	−0.309	0.757*	−3.035	0.002**
Task identity	−2.502	0.012**	−3.908	0.000**
Feedback	−2.540	0.011**	−2.586	0.010**
Task significance	−0.678	0.489*	−3.379	0.001**
Skill variety	−3.673	0.000**	−3.526	0.000**
Employee behaviour outcome				
Job commitment	−0.447	0.655*	−2.744	0.006**
Job satisfaction	−3.308	0.001**	−5.117	0.000**
Job stress	−5.149	0.000**	−1.975	0.000**

Table IV. Statistical significance analysis (Wilcoxon ranked test)

Notes: Null hypothesis: the median difference between pairs of observations is zero; *Maintain the null hypothesis: **Refuse the null hypothesis; n.a., not applicable (hard and soft practices levels before lean = 0)

The ability to promptly face the challenges of the market and satisfy new emerging customers' needs with high-performance and state-of-the-art technological solutions is one of the intrinsic characteristics of this company success.

In 2009, also due to the effect of the world economic crisis, Alpha felt the necessity to rethink its strategy and strengthened its identity. In 2010, the company decided to change the way of managing its production processes adopting LM principles to reduce customers' dissatisfaction due to delays in products delivery, its inability to properly control and manage the costs related to the process and high quantity of work-in-progress materials. In particular, Alpha's top management spent its first LM year to attend conferences, workshops and training courses to better understand the main challenges and opportunities coming from the adoption of a lean thinking philosophy.

The first application in production was launched in January 2011 (first phase: 2011-2013). Supported by an external consultant, it concerned of a pilot project focussed on a physical re-organisation of an existing assembly line. The project aimed at helping Alpha management and staff to get a deep understanding of how lean strategy has to be developed day-by-day, as well as to acquire the basic and fundamental knowledge necessary to expand the application of lean principles to the other production lines. Indeed, one year later, the company decided to extend its LM project, replicating the methods previously implemented in the pilot case to a second line and introducing in the first-line material handling optimisation techniques. The implementation of the LM hard practices was completed on the first line during the third year of the project, thanks to the introduction of approaches to improve equipment availability, flexibility and process quality. At the same time, some material handling optimisation techniques were applied on the second line, whereas a third lean project was launched in a third assembly line.

The fourth year marked an important turning point for the LM implementation in Alpha (second phase: 2014-2016). Indeed, it is from this year that Alpha started to emphasise the strategic role of lean culture through the implementation of specific techniques and methods devoted to enhancing continuous improvement and involvement within the organisation at every level (from management to operators) across the value chain from suppliers to customers. Moreover, the company started to launch the implementation of lean paradigm in other departments, including research and development, sales and marketing and administration.

4.4 Lean management practice implementation

As summarised in Tables V and VI, Alpha started the implementation of lean hard practices mainly focussing on the development of specific techniques and methodologies to support process efficiency, with an explicit interest in equipment layout (mean +2.73 and median +3.00) and material handling (mean +2.67 and median +3.00). In particular, the main actions were carried out to enhance the efficiency of the assembly lines, through the adoption of 5S standard, the introduction of innovative layouts enabling a single-piece production organization and the implementation of a Kanban scheduling approach supported by a "milk-run" material handling system (Mizosumashi), a Hejunka planning system and the definition of job standards (Kamishibai). The second phase of the lean manufacturing implementation was characterised by an acceleration of the physical re-organisation (mean +0.80 from 2.73 to 3.53 and median +1.00 from 3.00 to 4.00) and material handling logic (mean +1.40 from 2.67 to 4.07 and median +1.00 from 3.00 to 4.00). In particular, the re-layout was extended to the whole organisation, while the introduction of a material handler speeded up the transformation towards a flow production system. During this phase, Alpha also focused on pursuing efficiency and effectiveness by improving equipment availability (autonomous maintenance: mean +1.20 from 2.30 to 3.50 and median +1.00 from 2.50 to 3.50) and process quality (statistical process control: mean +1.00 from 2.32 to 3.32 and median +2.00 from 2.00 to 4.00), through the introduction of total productive maintenance, total quality management tools and Andon boards. Moreover, JIT delivery by suppliers and set-up time reduction techniques (single minute exchange of die) were further introduced to extend the Kanban system upstream and to gain more flexibility.

Several soft practices were also applied to ease the success of lean implementation. As shown in Tables V and VI, the first of LM implementation was characterised by a strong focalisation on improving top management leadership (mean +2.30 and median +2.00): project goals and values were set and adequate resources and funding were provided to establish a system to properly plan, manage and measure process performance (Hoshin

Table V.
Received responses-LM practice implementation

	Before lean implementation							First phase							Answers variation (%)		
			Distribution of answers (%)							Distribution of answers (%)							
	Mean	Median	1	2	3	4	5	Mean	Median	1	2	3	4	5	<	=	>
Hard practices																	
Autonomous maintenance	0,00	0,00	0	0	0	0	0	2,30	2,50	40	10	30	20	0	0	0	100
Equipment layout for continuous flow	0,00	0,00	0	0	0	0	0	2,73	3,00	0	47	33	20	0	0	0	100
Just In Time delivery supply	0,00	0,00	0	0	0	0	0	1,60	2,00	40	60	0	0	0	0	0	100
Kanban	0,00	0,00	0	0	0	0	0	2,67	3,00	7	27	60	7	0	0	0	100
Set-up time reduction	0,00	0,00	0	0	0	0	0	2,00	2,00	20	60	20	0	0	0	0	100
Statistical process control	0,00	0,00	0	0	0	0	0	2,32	2,00	24	28	40	8	0	0	0	100
Soft practices																	
Continuous improvement	0,00	0,00	0	0	0	0	0	1,94	2,00	31	49	14	6	0	0	0	100
Customer involvement	0,00	0,00	0	0	0	0	0	2,00	2,00	20	60	20	0	0	0	0	100
Small group problem solving	0,00	0,00	0	0	0	0	0	1,80	2,00	44	32	24	0	0	0	0	100
Supplier partnership	0,00	0,00	0	0	0	0	0	2,00	2,00	0	100	0	0	0	0	0	100
Top management leadership	0,00	0,00	0	0	0	0	0	2,30	2,00	35	20	25	20	0	0	0	100
Training employees	0,00	0,00	0	0	0	0	0	2,57	3,00	10	23	67	0	0	0	0	100

(*continued*)

Table V.

	First phase							Second phase							Answers variation (%)		
			Distribution of answers (%)							Distribution of answers (%)							
	Mean	Median	1	2	3	4	5	Mean	Median	1	2	3	4	5	<	=	>
Hard practices																	
Autonomous maintenance	2,30	2,50	40	10	30	20	0	3,50	3,50	0	20	30	30	20	0	10	90
Equipment layout for continuous flow	2,73	3,00	0	47	33	20	0	3,53	4,00	0	13	33	40	13	0	27	73
Just In Time delivery supply	1,60	2,00	40	60	0	0	0	2,40	2,00	20	40	20	20	0	0	40	60
Kanban	2,67	3,00	7	27	60	7	0	4,07	4,00	0	7	7	60	27	0	0	100
Set-up time reduction	2,00	2,00	20	60	20	0	0	2,60	3,00	20	20	40	20	0	0	40	60
Statistical process control	2,32	2,00	24	28	40	8	0	3,32	4,00	0	28	16	52	4	0	8	92
Soft practices																	
Continuous improvement	1,94	2,00	31	49	14	6	0	3,03	3,00	9	23	31	31	6	0	20	80
Customer involvement	2,00	2,00	20	60	20	0	0	3,20	3,00	0	20	40	40	0	0	0	100
Small group problem solving	1,80	2,00	44	32	24	0	0	2,64	3,00	20	24	28	28	0	0	28	72
Supplier partnership	2,00	2,00	0	100	0	0	0	3,00	3,00	0	20	60	20	0	0	20	80
Top management leadership	2,30	2,00	35	20	25	20	0	3,45	4,00	15	5	10	60	10	0	25	75
Training employees	2,57	3,00	10	23	67	0	0	3,47	4,00	3	7	30	60	0	0	20	80

Table VI.
Received responses-Physical work environment and job characteristics, Employee behaviour outcome

	Before lean implementation							First phase							Answers variation (%)		
			Distribution of answers (%)							Distribution of answers (%)							
	Mean	Median	1	2	3	4	5	Mean	Median	1	2	3	4	5	<	=	>
Physical work environment characteristics																	
Functional comfort	2,70	3,00	5	32	31	8	5	2,93	3,00	7	17	57	12	6	10	52	38
Workplace spatial arrangements (Layout)	2,89	3,00	7	21	33	14	6	3,07	3,00	5	16	51	23	5	11	58	31
Workplace cleanliness	3,19	3,00	7	14	27	23	10	3,46	3,00	2	14	36	32	16	7	56	37
Ambient properties	3,44	4,00	0	16	24	30	11	3,28	3,00	1	15	46	31	7	20	69	11
Workplace safety	3,49	4,00	2	6	31	34	8	3,85	4,00	1	1	27	52	19	2	63	35
Job characteristics																	
Autonomy	3,44	4,00	4	13	22	27	15	3,46	4,00	7	10	31	33	19	15	63	22
Task identity	2,81	3,00	7	26	30	11	7	3,09	3,00	2	23	43	25	6	9	54	37
Feedback	2,64	3,00	12	25	30	8	6	2,93	3,00	6	22	48	20	4	10	56	35
Task significance	3,28	3,00	2	16	33	17	13	3,33	3,00	2	16	43	22	16	9	70	21
Skill variety	2,89	3,00	6	25	32	8	10	3,27	3,00	6	14	41	26	14	6	48	46
Employee behaviour outcome																	
Job commitment	3,54	4,00	0	15	23	27	16	3,57	4,00	1	12	28	44	14	15	67	19
Job satisfaction	3,56	4,00	3	9	27	24	18	3,15	3,00	1	23	41	28	6	44	40	16
Job stress	2,77	3,00	15	15	30	16	5	3,43	4,00	9	11	26	37	17	4	42	54

(*continued*)

Table VI.

	First phase							Second phase							Answers variation (%)		
			Distribution of answers (%)							Distribution of answers (%)							
	Mean	Median	1	2	3	4	5	Mean	Median	1	2	3	4	5	<	=	>
Physical work environment characteristics																	
Functional comfort	2,93	3,00	7	17	57	12	6	3,26	3,00	7	12	36	36	9	1	67	32
Workplace spatial arrangements (Layout)	3,07	3,00	5	16	51	23	5	3,49	4,00	5	7	33	42	12	2	59	38
Workplace cleanliness	3,46	3,00	2	14	36	32	16	3,81	4,00	2	7	22	42	26	2	64	33
Ambient properties	3,28	3,00	1	15	46	31	7	3,83	4,00	5	6	21	37	31	7	35	58
Workplace safety	3,85	4,00	1	1	27	52	19	4,07	4,00	0	4	16	49	31	1	74	25
Job characteristics																	
Autonomy	3,46	4,00	7	10	31	33	19	3,77	4,00	7	4	25	33	31	7	62	31
Task identity	3,09	3,00	2	23	43	25	6	3,42	3,00	2	17	32	32	16	5	64	31
Feedback	2,93	3,00	6	22	48	20	4	3,11	3,00	5	23	32	35	5	6	67	27
Task significance	3,33	3,00	2	16	43	22	16	3,56	4,00	4	10	32	36	19	2	73	25
Skill variety	3,27	3,00	6	14	41	26	14	3,57	4,00	2	14	30	33	21	4	72	25
Employee behaviour outcome																	
Job commitment	3,57	4,00	1	12	28	44	14	3,77	4,00	1	10	22	44	22	5	75	20
Job satisfaction	3,15	3,00	1	23	41	28	6	3,62	4,00	0	11	32	40	17	5	52	43
Job stress	3,43	4,00	9	11	26	37	17	3,20	3,00	9	21	27	28	15	35	48	17

Kanri). Moreover, necessary mechanisms to enable a cultural change across the whole organisation were implemented through the development of training programs involving the whole organisation (mean +2.57 and median +3.00). During the second phase, Alpha extended its focus towards the establishment of a lean culture at the operational level, translating strategic goals into day-by-day actions. This goal was achieved by applying techniques and methods to implement structured practice routines (Kata pattern) involving employees, customers and suppliers in a continuous improvement loop (Plan-Do-Check-Act cycle).

4.5 Physical work environment characteristics

On average, physical work environment characteristics improved with the implementation of LM practices (Tables V and VI), with a greater advance during the second phase, in particular for ambient properties (mean +0.55 from 3.28 to 3.83 and median +1.00 from 3.00 to 4.00) and workplace layout (mean +0.42 from 3.07 to 3.49 and median +1.00 from 3.00 to 4.00). During the first phase, workplace safety received the highest progress (mean +0.36 from 3.49 to 3.85), whereas ambient properties downgraded (mean −0.16 from 3.44 to 3.28 and median −1.00 from 4.00 to 3.00).

4.6 Job characteristics

All the job characteristics improved during the first and the second phases (Tables V and VI), with a higher degree during the second phase. Specifically, during the first phase, modifications on job characteristics mostly affected the degree of skill variety required to carry out the work (mean +0.38 from 2.89 to 3.27) and the establishment of feedback loops towards both the operators and the managers (mean +0.29 from 2.64 to 2.93). On the contrary, job autonomy did not change. During the second phase, a clearer identification of the "piece of work" to be carried out by the workers (task identity: mean +0.33 from 3.09 to 3.42), as well as more freedom, independence and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out (mean +0.31 from 3.46 to 3.77), was obtained. Also, in this second phase, skill variety range was enlarged (mean +0.30 from 3.27 to 3.57 and median +1.00 from 3.00 to 4.00).

4.7 Employee behaviour outcome

As reported in Tables V and VI, during the first change, employee behaviour outcome worsened: job stress increased (mean +0.66 from 2.77 to 3.43 and median +1.00 from 3.00 to 4.00) and job satisfaction decreased (mean +0.41 from 3.56 to 3.15 and median −1.00 from 4.00 to 3.00). However, during the second phase, conditions improved: a higher job satisfaction was revealed (mean +0.47 from 3.15 to 3.62 and median +1.00 from 3.00 to 4.00) and stress level was reduced (mean −0.23 from 3.43 to 3.20 and median −1.00 from 4.00 to 3.00). Job commitment increased in both phases, with a greater degree during the second change. However, as shown in Table IV, the increse of committment that happened during the first phase of the project, is not statistically validated.

4.8 Operational outcome

Table VII discusses the effects of changes introduced by LM on operational performance. Positive values indicate an improvement in the performance indicator and negative values represent a decline in performance. All the values reported in Table VII are positive, demonstrating that LM contributes to achieving superior performance. However, the size of improvement varies among the operational indicators and between Phases 1 and 2.

In particular, the introduction of LM practices during the first phase brought the largest improvements in all the indicators (+2.6 on average). During the second phase, only speed shown a small advance (+1.0).

5. Discussion of results

Quantitative data, combined with semi-structured interviews with both operators and managers, support the discussion of results and the definition of relationships between the selected variables.

5.1 The effect of lean management practices on physical work environment characteristics and job characteristics

As shown by data analysis, during the first and the second phases of the lean project development, the level of both soft and hard practices adoption increased. At the same time, an improvement occurred in all the physical work environment and job characteristics items, except for the ambient properties, which level reduced even though such variation cannot be considered statistically significant. In conclusion, data suggest that the implementation of hard and soft LM practices may lead to positive effects of physical and organisational working conditions. However, quantitative data analysis does not provide any support to understand how hard and soft practices can act on work environment and job characteristics. Differently, interesting considerations in this sense can be extrapolated from qualitative analysis. Indeed, interviews suggest that physical work environment characteristics are mostly affected by the implementation of hard *practices*: for example, the introduction of techniques aiming at arranging the equipment layout for a production continuous flow (i.e. 5s), combined with a Kanban system, had a positive effect on workplace safety and cleanliness:

> First of all, we decided to focus our attention to making our collaborators more confident on lean management initiatives, by providing cleaner and safer working stations. (Lean Manager)

> Actually, sometimes I wish I do not have to clean my working station as requested (especially at the end of a long working day), but I know that such activity is fundamental for maintaining a good feeling and they also pay me to do it! (Operator)

However, in the second phase, the positive effect of hard practices was amplified by a higher degree of worker's involvement in continuous improvement activities. The greatest effects were observed in the workplace layout, designed by the operator itself, and in the ambient properties, defined on the basis of operator's perceived comfort. Such consideration further explains why the variation of the two aforementioned parameters was not supported by statistical validity in the first part of the project:

Operational performance	First change	Second change	Overall change
Quality	2.0	0.0	2.0
Speed	3.0	1.0	4.0
Dependability	2.0	0.0	2.0
Flexibility (mix and volume)	4.0	0.0	4.0
Cost	2.0	0.0	2.0
Mean	*2.6*	*0.2*	*2.8*

Table VII. Operational outcome – responses

> The self-organisation of the working station, in accordance with the lean management standards, is the natural consequence of our idea about employees' engagement. We do believe that each operator should have the opportunity to take part of the continuous improvement process playing an active role in all those initiatives that Alpha has launched to improve the production plant configuration and organisation. (Lean Manager)

> Thanks to the opportunity to organise my working station as I desire, I feel as I was at "home". I can work better and with less stress (Operator)

From a qualitative point of view, it can be also argued that job characteristics are to a large extent related to the implementation of lean soft practices. More specifically, the interviews found evidence of a relationship between training activities and the degree of skill variety: through cross-training programmes, supported by a job rotation policy, workers are trained on all the different tasks, duties and responsibilities related to a specific work cell or work area. Cross-training provides workers with a clear understanding of the entire team function and the multiple tasks within the cell:

> People improve their competences and thus their contribution to our operations performances only when they have the opportunity to apply their ideas. I do prefer a failed project due to a wrong application than zero results because of no proposals. (General Manager)

> I'm so happy for being part of this lean manufacturing training program. Since I have been involved, I have felt more confident in what my work consisted in and on which are the implications of my day-by-day decisions on my colleagues' work. (Operator)

A positive relationship between management leadership and the implementation of feedback loops can be also identified: for example, with daily gemba walks ("go to the place where people create value") managers support operators keeping track of how work is progressing, rapidly identifying problems where and when they occur and facilitating conversations about where it could improve:

> Before this project, I used to solve problems from my office's desk. Now I spend the majority of my working day together with the operators. It takes time, but the performances have increased a lot, indeed! (Production Manager)

> This project gave me the opportunity to collaborate directly with my boss and to make my opinion worth. (Operator)

The intensity of such relationships grows if hard methods for job organisation (i.e. practices for continuous flow equipment layout and Kanban system – including 5s, Mizosumashi and Kamishibai) are implemented, with a positive effect on task identity too. Indeed, job autonomy and significance grew (with a statistical significance) during the second phase when worker's involvement in continuous improvement activities was implemented, demonstrating that theoretical training programmes create the bases for the improvement but are not sufficient to make the change real.

In conclusion, we can state that the implementation of hard LM practices leads to improved physical work environment characteristics (to a larger extent than soft practices) and to improved job characteristics (in particular when considering equipment layout for continuous and Kanban practices). Moreover, the implementation of soft LM practices leads to improved job characteristics (to a larger extent than hard practices) and improved physical work environment characteristics (in particular when considering involvement in continuous improvement practices).

5.2 The effects of physical work environment and job characteristics on employee behaviour outcome

As underlined by data analysis, physical work environment and job characteristics' trends may differ from the employees' behaviour outcomes tendency. Indeed, during the first phase of LM project, a reduction of employees' satisfaction and an increase of their stress happened. At the same time, a negligible (and not statistically significant) increase of commitment occurred. On the contrary, during the second phase of the lean project, the increase in physical work environment and job characteristics corresponded to a significant improvement of job satisfaction, commitment and to a stress reduction. This result suggests that employee behaviour outcome may be influenced by other factors, such as the type of practices adopted and their level of implementation, as also underlined by the interviews. Indeed, during the first phase of the changeover to lean, the employee behaviour outcome worsened mostly due to changes introduced in job characteristics. Improvements in the physical work environment did not seem able to compensate job characteristics modifications, demonstrating that workers give greater importance to the way their tasks are organised than the environment they work within (excluding safety aspects, addressed as primary important dimension). In particular, having a larger range of skills and feedback information about how work is progressing could cause, in the first place, a lower job satisfaction and a higher stress:

> After implementing lean methodologies my working conditions have improved a lot! My work is still heavy, anyway! Indeed, my activities have become easier but I have much more responsibilities and different task to perform. (Operator)

> Before lean, I was involved in a specific production phase. It was so boring but much easier. Now I have a wider view of the whole assembly process, making additional tasks in other assembly lines sometimes. Next month I will start a new training program to learn how to conduct set-up and simple maintenance activities. I like it but it is so stressful. (Operator)

A higher involvement in continuous improvement activities, placing at the centre of the change the worker as an active agent of the change and not as a passive element, improves job autonomy and job significance, with positive consequences on workers in terms of higher commitment, reduced stress and greater satisfaction:

> Finally, I feel part of this company and a key contributor to its results. (Operator)

> I'm so happy because the process of change that this company is experiencing is also due to my contribution. (Operator)

In addition, it was found that the human responses to the job characteristic factors depend on individual differences. However, this consideration is only qualitative as not statistically demonstrated, due to the sample size.

- The higher the age and the years of experience in the company of the respondents the lower their satisfaction and commitment towards LM, whilst a direct relationship with stress emerges. Results underline the existence of a direct relationship between lean and cultural change and that lean approach encounters major difficulties if implemented in organisations where the capabilities that have been acquired over time may limit management engagement in adaptive change.
- Different types of commitments emerge considering the educational level of respondents, their age, their work experience and the type of contracts. In particular, people with a primary school educational level subject to short-term contracts

present the highest level of commitment in doing activities. Young people with a very short experience are characterised by a high level of commitment to taking operational decisions, whereas people with a high educational level declare having a very strong commitment in creating new solutions. Such results underline how lean manufacturing facilitates cooperation at any level of the organisation, eliminates cultural barriers and stimulates vertical and horizontal information sharing.

- Satisfaction and commitment are higher in those departments where specific lean projects were developed. Moreover, people involved in training activities and lean projects declare a major satisfaction and commitment. Conversely, workers who did not participate in any lean project appear dissatisfied and not happy about the company. This result underlines how an effective communication system could avoid internal dissatisfaction especially for workers who were not involved in lean initiatives.

In conclusion, we can state that improved physical work environment and job characteristics lead to employee behaviour outcomes. In particular, improved job characteristics lead to employee behaviour outcome (to a larger extent than physical work environment characteristics), with the moderating role of individual characteristics.

5.3 The overall effect on operational outcome

Data analysis indicates that the relation between operational outcomes and work environmental characteristics, job characteristics and employee behaviour can change overtime. Indeed, while operational outcomes increased during the first phase, they remained the same during the second phase of the project, characterised by an increase of work environmental and job characteristics, as well as employee behavioural outcome. Discussion with managers and employees showed that in the short term, higher operational performances were achieved through changes in physical work environment and job characteristics. For example, investments in methods for creating a continuous flow and in the establishment of a Kanban system improved workplace characteristics that, in turn, contributed to achieving higher speed and volume flexibility. Considering job characteristics, a higher level of skill variety directly influenced flexibility results. In addition, qualitative analysis suggests that work environment and job characteristics influence operational outcome in the short term. Moreover, changes in operational outcome were observed also in the long term as indirect influence of physical work environment and job characteristics changes, acting through employee behaviour outcome modifications, demonstrating that better employee behaviour outcome will lead to improved operational outcome in the long term.

From the discussion of results, an updated model, which reflects results, could be drawn (Figure 2).

6. Conclusion

Relationships between the social and technical components of a LM system are complex and determine the overall system performance in both the short and the long term. In this paper, a comprehensive model that includes and connects technical, physical, cognitive, organisational, social and performance variables related to the implementation of a LM approach is proposed. The research model variables were identified through an extensive multi-disciplinary literature review, whereas critical insights about how these variables are connected were empirically gained through an

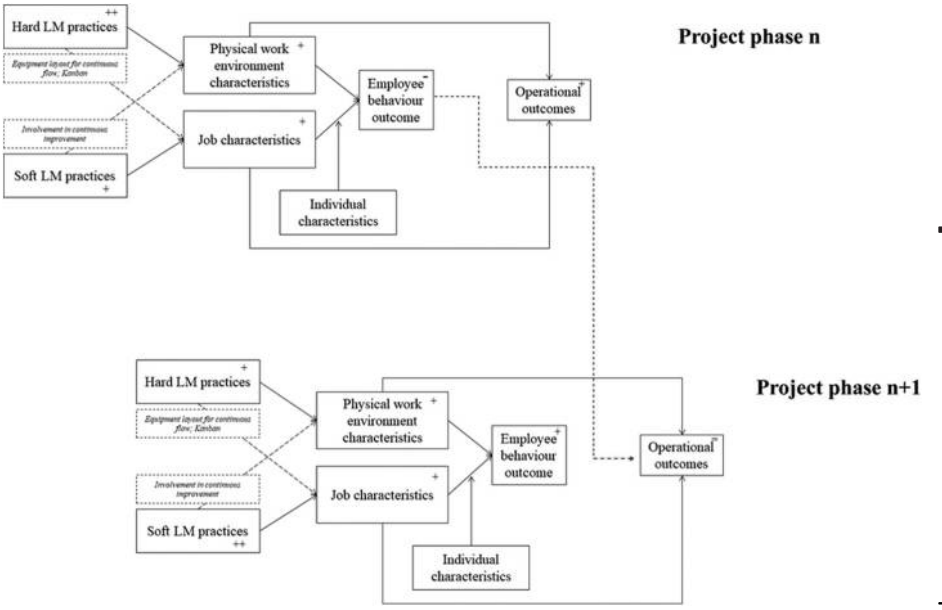

Figure 2.
The final model

in-depth single exploratory case study. Both qualitative and quantitative methods were used to build empirical evidence. Results show a direct relationship between hard and soft practices implementation and physical work environment and job characteristics, which, in turn, directly affect operational outcome in the short term. Hard practices have a higher impact on physical work environment characteristics, whereas soft practices mostly affect job characteristics. In the long term, operational performance is influenced by employee behaviour outcome, conditioned by physical work environment and, mainly, by job characteristics with the moderating effect of individual characteristics.

This model can help practitioners build a roadmap for a LM implementation, considering the role of human factors to achieve superior operational performance. Based on the roadmap, an implementation monitoring system could be developed to check how the social and technical components of the LM system evolve over time. Moreover, the identification of the moderating effect of individual characteristics on the relationship between job characteristics and operational outcome could support the definition of specific training programs, tailored for specific workers' typologies.

As a single case study, a generalisation appears clearly limited. However, the purpose here is the theoretical generalisation in a model that in the future should be tested to verify statistical significance of propositions and to assess the relative impacts of each measurement variable and construct, also considering a longer timeline. Several extensions of the model could be proposed:

- evaluation of the effect of rewarding systems on employee behaviour outcome and employee operational outcome;
- inclusion of middle and top manager behaviour outcome and evaluation of its effect on operational outcome;

- expansion of the performance construct to other types of performance, in line with a triple bottom line approach (economic, environmental and social); and
- evaluation on how the evolution of technology and in particular smart technologies can lead to the amplification of benefits for company operations, as well to influence workers' environmental (physical and psychological conditions), thus influencing their behavioural outcome.

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