SAFETY RELOADED: LEAN OPERATIONS AND HIGH INVOLVEMENT WORK PRACTICES FOR SUSTAINABLE WORKPLACES*

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ABSTRACT

Using an original dataset of 32 production departments from 9 plants in 7 countries of one of the world's largest tyre producers, this study applies a variety of regression analyses to investigate the effects of Lean Operations, High Involvement Work Practices and Management Behaviors on occupational safety.

The study tests and finds support for the hypothesis that Lean Production systems positively affect occupational safety. In addition, we find that High Involvement Work Practices and two specific management behaviors - workers' capability development (coaching and teaching of workers) and empowerment (autonomy and participation of workers in developing their own job standards) - positively affect occupational safety. Furthermore, empowering behaviors positively moderate the effect of Lean Operations on workers' safety. The study bridges lean, behavioral and sustainable operations literature with theories related to the ethical side of safety management, ethical leadership and sustainable HRM. In doing so, this work contributes to the understanding of occupational safety as constitutive aspect of organizational sustainability.

Keywords: Lean Production, High Involvement Work Practices, Occupational Safety, Sustainable Operations, Work Standards, Management Behaviors

INTRODUCTION

With the recent quest to underscore and promote the human side of organizational sustainability (Carroll and Buchholtz, 2014; Pfeffer, 2010; Schwartz and Carroll, 2003), the issue of occupational safety in the workplace has drawn renewed attention for its operational, social and ethical implications. So far, most of the research at the crossroads of ethics and workplace safety has prevalently focused on the link between the safety climate and safety events (Cullen et al., 2003; Martin and Cullen, 2006; Parboteeah and Kapp, 2008; Wimbush and Shepard, 1994; Zohar, 1980, 2000). Alternatively, studies have centered on how instrumental and normative perspectives influence the meaning of ethics, the effectiveness of CSR, and occupational safety outcomes (Hart, 2010, 2013). However, the impact of organizational practices and management behaviors on occupational safety seems to be, at the least, an equally important dimension of social sustainability, which runs the risk of remaining underdeveloped (Raiborn and Payne, 1996; Taylor et al., 2012). This study empirically investigates how organizational practices and management behaviors affect occupational safety. Hence, we explore the human side of organizational sustainability, focusing on a widely applied and studied set of practices: Lean Production systems.

A sizable body of empirical research has analyzed the relationship between Lean Production and organizational performance, broadly converging on positive effects on productivity, quality and even financial performance (e.g. Bou and Beltran, 2005; Browning and Heath, 2009; Callen et al., 2000; Challis et al., 2002; Chandler and McEvoy, 2000; Claycomb et al., 1999; Cua et al., 2001; Flynn et al., 1995; Hart and Schlesinger, 1991; Huson and Nanda, 1995; Kaynak, 2003; Krafcik, 1988; Lewis, 2000; Losonci and Demeter, 2013; Mackelprang and Nair, 2010; Powell, 1995; Sakakibara et al., 1997; Samson and Terziovski, 1999; Shah and Ward, 2003; White et al., 1999; Wood, 2004; Youndt et al., 1996).

Instead, how Lean Production practices affect employee outcomes remains a very controversial area (Parker, 2003). The empirical evidence on the social performance effects of Lean Production systems is mixed (Genaidy and Karwowski, 2003; Parker, 2003) as well as the findings on their ethical implications (Hummels and de Leede, 2000). On one side of the debate, Lean Production systems are found to impose greater job demands on workers with limited participation and intense work pressure. Moreover, these systems have negative effects on health, well-being and motivation outcomes (Babson, 1993; Delbridge et al, 1992; Landsbergis et al., 1999; Lewchuk and Robertson, 1996). On the other side, Lean Production is considered a human-centered system generating positive outcomes as concerns the quality of the work environment (Adler, 1993; Mullarkey et al., 1995).

Interestingly, this controversy has recently re-captured the attention of scholars (Longoni et al., 2013). In fact, given the mounting social and regulatory pressures towards more sustainable operations and working environments (Hart, 2013; Kleindorfer et al., 2005; Lorenzo et al., 2009), occupational health and safety have come to the forefront of academic and managerial debate (Pagell et al., 2013).

However, the few rigorous studies relating Lean Production systems, Human Resource Management and occupational health and safety tend not to acknowledge this broader perspective. Instead said research adopts a more specialist and pragmatic view, rich in practical and theoretical implications, but unable to frame the investigation of the relationship between Lean Production and safety outcomes within the debate on socially sustainable operations and organizations (Longoni et al., 2013; Zanko and Dawson, 2012).

Our study intends to start filling this gap by integrating theories from Lean Operations, High Involvement Work Systems, Work Psychology, Leadership and Safety literature to analyze the impact of Lean Operations, High Involvement Work Practices and management behaviors on occupational safety.

We argue that Lean Production has a positive effect on worker safety when correctly and fully applied as a system of operational practices. Additionally, on one hand we build on extant studies on the effects of High Involvement Work Practices (Barling et al., 2003; Longoni et al., 2013; Parker, 2003; Zacharatos et al., 2005) to explore the direct effects of workers' involvement and opportunities for them to grow and to contribute to occupational safety in Lean Operations Systems. On the other hand, we draw upon Behavioral Operations literature (Bendoly et al., 2006; Bendoly et al., 2010; Gino and Pisano, 2008; Loch, 2007) and studies of management behaviors in Lean environments (Byrne, 2012; Emiliani, 1998, 2003; Liker, 2004; Liker and Ballé, 2013; Liker and Convis, 2012; Liker and Hoseus, 2008; Linderman et al., 2010; Mann, 2009; Rother, 2009; Seddon, 2005; Womack, 2011) to investigate the direct effects and interaction of production managers' empowering and capability development behaviors on workers' safety.

Adopting an "Insider Econometrics" approach (Bartel et al., 2004), we conduct a multi-plant and multi-production department single-firm study. Extensive field research allowed us to collect and analyze primary data on 32 production departments from one of the world's largest tyre producers in 9 plants located 7 countries: Italy, UK, Germany, Turkey, Romania, Argentina and Brazil. We find that Lean Operations, High Involvement Work Practices, and the active role of production managers in workers' empowerment and capability development are all factors which positively impact safety.

The paper is structured as follows. In the next section we review the literature on occupational safety related to Lean Production Systems and High Involvement Work Practices and we develop the model and the hypotheses of our study. Then, we describe the empirical setting and the study methods, data and analysis. Finally, we present our findings, highlighting this study's contribution and limitations, as well as opportunities for further research.

THEORY AND HYPOTHESES

Lean Operations, High Involvement Work Practices and Management Behaviors

Operations Management literature defines Lean Production as an integrated set of socio-technical practices aimed at eliminating waste along the whole value chain within and across companies (Holweg, 2007; Womack et al., 1990). A large body of empirical work suggests that it is by implementing "bundles" of Lean Operations practices that companies achieve high performance, due to the synergistic effects among such practices (Schroeder and Flynn, 2001).

We follow this approach recalling that Taiichi Ohno (1988), in his foundational work on the Toyota Production System, maintains that "what made Toyota stand out is not any of the individual elements, but having all the elements together as a system and practicing them every day in a very consistent manner, not in spurts." From this perspective, lean production can be defined as "a multi-dimensional approach that encompasses a wide variety of both technical and management practices" (Shah and Ward, 2003, p. 129). The heart of lean production does not lie in the application of specific tools and artifacts, but rather in a business philosophy able to cultivate leadership, teams and culture, to devise strategy and to maintain a learning organization (Fine et al., 2008; Liker, 2004).

Along this vein, our study concentrates on the multiple dimensions of lean production systems following Shah and Ward's (2007) approach. Accordingly, we define lean production as an integrated system whose main objective is to eliminate waste by concurrently reducing or minimizing variability with regard to suppliers, customers, and internal processes. We adapt this approach and the corresponding dimensions to our empirical setting, focusing on the 'internal' dimensions of Lean Production systems they propose. These 'internal' dimensions correspond to the following five sets of Lean Operations Practices: PULL (pull system based on Kanban and supermarkets facilitating JIT), FLOW (continuous or one-piece-flow based on manufacturing cells), SETUP (setup time reduction through quick changeovers and single minute exchange of dies - SMED), TPM (total productive/preventive maintenance and workplace organization - 5S) and SPC (statistical process control and visual management devices).

Beyond the role of Lean tools, many studies also point to the importance of High Involvement Work Practices to enable operational results at the plant level (Ichniowski et al., 1997: MacDuffie, 1995). We integrate this perspective within our study as well, and offer a comprehensive view with regard to the effect of organizational practices on workplace safety. To do so, we make reference to the stream of research focused on the role of employee involvement, participation and multi-skilling in shaping sustainability results (Dubois and Dubois, 2012; Pless, Maak and Stahl, 2012; Taylor et al., 2012).

Furthermore, our analysis includes the role of management behaviors as a key factor potentially enhancing (or hindering) the effect of lean operations on safety (Pagell et al. 2013; Veltri et al., 2013). In this respect, we focus on two specific behaviors: 1) the extent to which production managers nurture workers' capability development, playing their role as teachers and coaches (Liker, 2004; Spear and Bowen, 1999); 2) the extent to which production managers empower workers, granting them autonomy and encouraging their participation and active involvement with specific regard to setting their own work standards (Adler et al., 1997; DeTreville and Antonakis, 2006).

A detailed explanation of the constructs and associated measures is reported in the methodological section of this study.

Lean Operations Practices and Safety

The theory and empirical evidence on the effects of the adoption of Lean Operations practices on employees' outcomes is controversial (Conti et al., 2006; DeTreville and Antonakis, 2006; Genaidy and Karwowski, 2003; Parker, 2003). This makes the topic of implementing Lean Operations practices particularly interesting in light of our aim to effectively explore the human side of organizational sustainability. On the one hand, Lean Production has been branded "Management by Stress" and "Mean Production" (Babson, 1993; Harrison, 1994). The reason for this is that it imposes greater job demands and intense work pressure, but with limited decision authority and negative health, well-being and motivation outcomes (Brenner et al., 2004; Fucini and Fucini, 1990; Landsbergis et al., 1999; Lewchuck et al., 2001). The logical premise of this critical perspective is the existence of a trade-off between Operations and Safety Management (and between operational outcomes, such as productivity and quality, and occupational safety outcomes such as the reduction of accidents, injuries and near misses). This in spite of the frequent overlap of the management and operational practices suggested by the two disciplines (Veltri et al., 2013).

On the other hand, Lean Production has been often associated with safer, high-quality and high-commitment work environments characterized by sustainable human performance (Adler, 1993; Genaidy and Karwowski, 2003; Liker, 2004; Mullarkey et al., 1995; Womack et al., 1990). In Lean environments, work is organized in order to minimize non-value-added activities, reduce unnecessary variability and avoid overburdening workers. This, in turn, leads to performance improvements across all the diverse performance dimensions, including productivity, quality, safety, ergonomics and morale (Black, 2007; Liker, 2004). For example reducing inventory and material costs deriving from the adoption of pull systems also leads to reduced work-related strains, unnecessary motion and material handling hazards. Similarly, by adopting standardized work, 5S and visual management techniques, companies can immediately identify abnormalities and surface problems, thus improving not only quality but also ergonomics and safety. Implementing TPM techniques and poka-yoke devices not only increases overall equipment effectiveness (OEE) via technology breakdown reductions and better operator/machine separation, but also decreases the probability that technologies are operated in ways that represent hazards for the operators (Birdi et al., 2008; Ledford, 1995; Oliver, 1991; Schonberger, 1982).

Interestingly, many Lean Operations practices increase the level of “transparency” of the workplace (clear visibility of hazards, cleaner working environment, etc.) so that workers have the opportunity to “identify, evaluate and suggest controls”. This helps to reduce workplace health and safety risks (Anvari et al., 2011). In particular, visual boards and other artifacts for visualization are devices that make human/technology interaction easier and more effective (the Jidoka concept), (Formoso et al., 2002). This means that it is possible to maintain effective and safe standards and procedures (Hirano, 1996) and facilitate continuous improvement processes (Bessant and Francis, 1999). In this way systems are able to provide information, signal deviations, control and guarantee the correctness of processes (Galsworth, 1997) and, in turn, improve safety in the workplace. Positive spillovers on safety outcomes derive from 5S and TPM practices which reduce machinery breakdowns. Moreover, by entitling workers with autonomy, skills and responsibility regarding maintenance, these practices enhance workers’ ownership of the process, facilitating prevention and control (Brunet and New, 2003; Longoni et al., 2013; Mckone et al., 2001; Sila, 2007).

Recent studies attempt to reconcile these controversial views and streams of empirical research, attributing relative inconsistency to the incomplete or erroneous implementation of

Lean Operations practices. Alternatively, other studies suggest that it is the variety and ambiguity of definitions and conceptions of Lean Production systems adopted in the literature (and of their constituent practices/dimensions), as well as the characteristics of the empirical methods and research designs, that generate contradictory results (Genaidy and Karwowski, 2003; Longoni et al., 2013; Parker, 2003; Womack et al., 2009). This reconciling view suggests that there is no trade-off between Operational and Safety objectives, and that they can be achieved jointly through the same system of practices, as long as these practices are internally consistent (Longoni et al., 2013; Pagell et al., 2013; Veltri et al., 2013).

We conceptually link this reconciling view with the approach to Lean Production proposed by Shah and Ward (2007). From this perspective, the safety and operational performance effects of Lean Production depend more on the “bundled” adoption of a whole set of practices than on the implementation of single practices (Lander and Liker, 2007; Spear and Bowen, 1999). Depending on how they are applied and combined, practices like continuous flow, kanban, TPM, 5S, standardized work, visual boards and continuous improvement based on structured problem solving, might either represent higher work “demands” or have the positive effect of work “energizers” (Genaidy and Karwowski, 2003). The negative effects of Lean Operations practices on workers’ safety derive from the greater “work demands” some of them might pose on workers, if they are not designed appropriately and implemented as part of a larger system. For example, the application of just-in-time (one-piece-flow and pull systems) without the possibility of stopping the production process in case of abnormalities is a typical case of incomplete adoption of Lean Production as a system. Indeed, it is the erroneous, inconsistent or incomplete adoption of Lean Operations practices that typically determines the imbalance – with work demands prevailing over work energizer effects - which endangers workers’ safety (Adler et al., 1997; Longoni, et al., 2013).

Consequently with this line of reasoning, we argue that the implementation of a Lean Production system (a consistent bundle of practices) has positive safety outcomes for workers. Hypothesis 1 follows.

Hypothesis 1: The implementation of systems of Lean Operations practices is positively associated with occupational safety.

High Involvement Work Practices and Safety

Since the seminal studies conducted at MIT in the context of the International Motor Vehicle Program, a specific set of Human Resource Management practices have been considered effective instruments to improve operational performance (Kochan et al., 1997; MacDuffie, 1995; Pil and MacDuffie, 1996; Youndt et al., 1996). These practices (teamwork, multi-skilling, job rotation, and decision rights delegation, to name a few) have come to be known as High Involvement Work Practices. They are almost always included in studies on the performance effect of Lean Production systems and conceptualized as the social side of these systems. The concurrent implementation of such practices, along with more operational ones, is usually considered a necessary condition to improve operational performance (Beauvallet and Houy, 2010; De Menezes et al., 2010; Ichniowski et al., 1997; MacDuffie, 1995; Macduffie and Krafcik, 1992; Shah and Ward, 2003, 2007) as well as safety (Longoni et al., 2013). High Involvement Work Practices enhance workers' skills and motivation (via appropriate work organization, communication, compensation and internal mobility systems) (Jiang et al., 2012), and provide the opportunity for employees to identify with the organization and feel an increased sense of ownership (Jiang et al., 2012; Lepak et al., 2006). These practices "are designed to empower employees to use their skills and motivation to achieve organizational objectives" (Jiang et al., 2012, p. 1267). Moreover, when High Involvement Work Practices are in place, the risks for workers' safety are reduced (Longoni et al., 2013). Employees' involvement facilitates their participation in continuous improvement processes (Conti et al., 2006; Perez Toralla et al., 2012) and increases the depth and breadth of their skills (Kaminski, 2001). Multi-skilling and job rotation mitigate the boredom of repetitive tasks, improving motivation and the level of attention (Womack et al., 2009). Participative problem-solving in teams favors the reduction of hazards through information sharing, mutual help and social monitoring (Brenner et al., 2004).

Also in this case, however, the effectiveness of these practices in reducing accidents, injuries and near-misses is contingent upon their integrated adoption as a bundle of practices, while piecemeal and fragmented adoption does not lead to sustained results (Longoni et al., 2013). The second hypothesis follows:

Hypothesis 2. The adoption of High Involvement Work Practices is positively associated with occupational safety.

Management Behaviors and Safety

Another fundamental dimension that might shape the safety performance of lean production systems relates to the behaviors that managers adopt to develop the skills necessary to safely perform production tasks, as well as to empower workers to actively participate and engage in promoting and improving safety. In lean production environments, empowering workers and developing their capabilities are internal processes grounded on specific management behaviors (Rother, 2009; Spear and Bowen, 1999). These behaviors have drawn increasing attention , especially in the more practitioner-oriented literature (Emiliani, 1998, 2003, 2008; Found and Harvey, 2006; Lucey et al., 2005; Shook, 2008; Van Dun et al., 2010).

This recent sharper focus on management behaviors in lean environments also derives from the widespread observation of the challenges involved in successfully imitating Toyota and implementing Lean Production Systems (Liker, 2004; Lucey et al., 2005; Pil and MacDuffie, 1996; Safayeni et al., 1991). The fact that management behaviors are more difficult to observe, study and replicate contributes to explaining why they are underinvestigated. Additionally, this clarifies why Lean Production is still prevalently considered, by scholars and practitioners alike, as a set of practices and artifacts (Lander and Liker, 2007; Spear and Bowen, 1999). The implication here is that the means (the practices) become ends in themselves, while companies lose sight of the true end: an overall efficient and effective production system (Browning and Heath, 2009).

The importance of management behaviors in Lean Production systems is also postulated by their intrinsic socio-technical nature (Lander and Liker, 2007; Spear and Bowen, 1999), and by the fact that they are "total systems" (Fujimoto, 1999, p. 87) characterized by specific patterns of information assets and information processing. Furthermore, some studies have highlighted that poor management may be an important cause of non-sustainable Lean transformations (Found and Harvey, 2006; Lucey et al., 2005).

Our study builds on the research pioneered by Womack (2011), complementing these findings with additional research drawn from other Lean Management and Lean Leadership-related works (Emiliani, 2003; Liker, 2004; Liker and Hoseus, 2008; Liker and Morgan, 2006; Ohno, 1988; Rother, 2009; Sato, 2008; Spear, 2004). These studies emphasize that, in organizational environments characterized by the successful implementation of Lean Production systems, there are recurrent patterns of management behaviors that typically include the following: a) 'Go and see' (make decisions on the basis of direct observation and a thorough understanding of the facts, directly at the point of value creation, tapping into the local knowledge of the employees involved in the operations); b) 'Use the scientific method for problem solving' (solve problems through "experiments", mobilizing team members' ingenuity in order to identify the root cause of problems; develop a wide set of countermeasures to experiment with; empirically test and evaluate them, deploy them); c) 'Ask why and show respect' (teach and coach, don't fix, helping and supporting the workers doing their jobs so that they become more knowledgeable; at the same time, appreciate their knowledge and efforts).

This view on the repertoire of management behaviors that characterize lean production environments, on the one hand, refers to the broader literature on the nature of management and leadership for sustainable performance, as developed by streams of thought and practice like evidence-based management (Pfeffer and Sutton, 2000, 2006), level 5 leadership (humility and determination) (Collins, 2001) and servant leadership (Greenleaf, 2002). On the other hand, this view ties into studies on responsible leadership (Maak and Pless, 2006; Szekely and Knirsch, 2005) and ethical leadership (Brown et al., 2006; Brown and Treviño, 2006), that converge in considering concern for others and fair treatment of employees (including respect and voice) examples of ethical leadership behaviors.

Capability Development

The first managerial behavior we focus on is the development of skills and human capital. We refer to capability development as the behavior through which managers focus (spend time) on teaching/instructing and coaching their subordinates, taking direct responsibility for people's capability development and co-practicing with subordinates' specific learning routines. Managers should coach, not fix (Spear, 2004). They teach Lean Operations practices/routines, tapping into workers' ingenuity and leaving room for workers' learning and autonomous initiative without imposing solutions (Liker and Convis, 2012). Indeed, learning on the job is an integrative part of work and work time for employees (Liker and Ballé, 2013; Spear and Bowen, 1999; Womack, 2011). Managers' explicit commitment to workers' on-the-job development results in more knowledgeable and motivated workers who have better competencies and more control over their jobs. As a result, they perform their jobs more safely (Barling et al., 2003; Jiang et al., 2012; Zacharatos et al., 2005). Moreover, capability development by managers improves organizational commitment which is also associated with safer working environments and higher safety orientation among workers (Zacharatos et al., 2005). Hypothesis 3 follows:

Hypothesis 3. Workers' Capability Development through on-the-job learning by line managers is positively associated with occupational safety.

Worker empowerment

The second managerial behavior we focus on is worker empowerment, i.e. the process of sharing power with workers "by delineating the significance of their jobs, providing greater decision-making autonomy, expressing confidence in the workers' capabilities, and removing hindrances to performance" (Zhang et al., 2010, p.109). Sharing power with subordinates translates into behaviors like leading by example, participative decision making, coaching, informing, and showing concern (Srivastava et al., 2006).

In our research context, the empowerment, participation and autonomy of workers are all fundamental to the creation of a safety culture (Parker et al., 1997; Veltri et al., 2013; Zacharatos et al., 2005). These aspects complement some typical work organization features of lean production systems, such as teamwork, and broader and richer jobs, all of which lead to positive safety outcomes (Genaidy and Karwowski, 2003; Parker, 2003). Workers' empowerment, autonomy and participation in the development, design and control of work standards represent the distinguishing feature of work standardization in Lean Production systems. Through more accurate and more fairly perceived work standards, this feature affects positive outcomes for employees (Adler and Borys, 1996). In lean production environments, work standardization is endowed with a "creative tension" (Womack et al., 1990) deriving from the autonomy and participation of workers in developing their own work standards (Adler, 1993). Autonomy and participation in the design and control of work standards increase workers' empowerment, perceived fairness and control, with positive effects on well-being and organizational commitment and a reduction of psychological strain (Parker, 2003). Autonomy and participation change the substantive and perceived nature of work standards, transforming them into sets of rules and routines that enable employees to gain control over and knowledge of their work, with positive outcomes in terms of learning, motivation, satisfaction and compliance (Adler, 1993; Adler and Borys, 1996). Creating a fair working environment via empowerment also represents typical caring actions that signal altruism and concern for workers (Brown and Treviño, 2006).

This, in turn, positively affects safety orientation and safety performance (Distelhorst et al., 2013). Hypothesis 4 follows:

Hypothesis 4. Workers' empowerment, autonomy and participation in developing their own work standards is positively associated with occupational safety.

Moderation Effects

The impact of empowering and capability development management behaviors on safety goes beyond the boundaries set by formal training processes and by granting decision and control rights over production to workers. Indeed, these behaviors influence the way in which Lean Operations practices affect organizational results (Zacharatos et al., 2005).

On the one hand, Lean Operations practices provide valid support for safety management when workers continuously learn and are motivated to apply their skills by developing and designing their work standards (Parker et al., 1997). On the other hand, workers are empowered by continuous on-the-job learning, which reinforces a shared perception of experimentation and tolerance for errors (MacDuffie, 1995). This is helpful in terms of successfully applying Lean Operations practices. Management behaviors emphasizing teaching and coaching obviously also improve workers' knowledge of specific Lean Operations practices (Shah and Ward, 2007), making the successful implementation of the latter more likely.

Managers' empowering behaviors, providing more autonomy and advocating more participation and involvement, allow individuals the discretion and the opportunity to decide how to implement Lean practices, and, hence, how to set their work standards. This fosters intrinsic motivation, a sense of belonging and identification (Grolnick et al., 1991), as well as creativity (Zhang and Bartol, 2010). As a result, under conditions of autonomy and participation, individuals have the chance to engage in curiosity and mastery attempts (deCharms, 1968), which in turn have the potential to make Lean Operations practices even more effective. Indeed, the effective implementation of such practices requires a trial and error approach and the freedom to determine autonomously the path and the experiments that are most useful for continuous improvement.

To sum up, when managers display empowering and capability-development behaviors, workers feel safe to experiment, make mistakes and learn, selecting the most effective course of action out of a repertoire of practices that they master. They are more likely to activate a true knowledge-building process, which could enhance Lean Operations practices by complementing them with actual behaviors that drive better safety results. Thus, we hypothesize that these management behaviors amplify the effect of Lean Operations practices on safety. Hypothesis five follows.

Hypothesis 5. The effect of Lean Operations practices on occupational safety is positively moderated by (a) empowering and (b) capability development production managers' behaviors.

Figure 1 summarizes the research constructs and the theoretical model comprising the research hypotheses.

Insert Figure 1 about here

METHODOLOGY

Research Setting

Given the focus of our study, we conducted a single-firm study using an “Insider Econometrics” approach, as this type of research is particularly appropriate for analyzing the performance effects of practices with key insights into production processes (Bartel et al., 2004). The setting for our study was one of the world’s leading tyre manufacturers, a publicly-traded company which operates in the consumer and industrial market segments. This constitutes an ideal setting to study the safety performance effects of Lean Production Systems, as the implementation of such systems represents a fundamental part of the company’s recent history. In fact, the company began to adopt Lean Operations practices back in the early 1990s, investing heavily in Total Productive Maintenance – TPM. (Tyre manufacturing is a capital-intensive production process.) Later the firm gradually widened the scope of the Lean Operations practices it implemented, moving to an early version of World Class Manufacturing and, in time, to its own original and company-specific adaptation of Lean Production. This system, formalized and introduced in all the producer’s plants starting in 2007, has become the production system for all 19 plants worldwide. The aim is to create a company-wide standard and develop corporate language to implement continuous improvement and quality management with the full involvement of the workforce. The system is explicitly founded on two sets of practices: ‘Operations’ (tools and techniques such as Value Stream Mapping, TPM, 5S, A3 based problem solving and Visual Management) and ‘People’, with a strong focus on training, teamwork, transparent communication, empowerment and rewarding.

Data and Sample

The producer under investigation has a global manufacturing footprint comprising 19 plants around the world. Despite their diversity in size, technology, product specialization, age and location, at the time of the study all the plants had adopted the company's 'official' Lean Production system. Naturally, the roll-out of Lean Operations and High Involvement Work Practices took place at different points in time and in different ways at the different plants. However, the producer displayed a long-standing commitment to lean production, and the governance system included features for horizontal, cross-plant information exchange, learning and support (yokoten) and uniform support from the headquarters in the form of training, consulting, and so forth. These considerations make it reasonable to assume that all the plants were treated and supported homogeneously. Hence, no structural differences exist in the degree of exposure (and of knowledge endowment) of the plants to Lean Production.

Based on this assumption, 9 plants were selected for the study. After a first random draw of 10 out of the total 19, the authors discussed the selected set with the company's top Operations Management team. Subsequently, we adjusted the sample as follows: nine plants in seven countries with two in Italy, one in UK, one in Germany, one in Turkey, one in Romania, one in Argentina and two in Brazil. The plant in China was excluded from the sample for research logistics and budget constraint issues. The unit of analysis of the study is the production department (internally defined as a 'mini-factory') corresponding to each of the five typical phases of the tyre production process: Banbury, Semi-Finishing, Building, Curing, and Finishing. We initially obtained a sample of 44 production departments (mini-factories). Due to missing data, the final sample is made up of 32 observations. (Some respondents did not complete the research protocol.)

Over the period 2008-2009, we traveled extensively worldwide visiting the plants in our sample one or more times. During each visit, we conducted repeated plant tours, collecting primary and secondary qualitative and quantitative data. Usually each visit lasted two days. On the first day, we compiled qualitative descriptions of the general plant characteristics such as organizational structure, product specialization, production volume, workforce, unionization, and the local context. Moreover, we gathered information about the plant history and the various stages of implementation of Lean Operations and High Involvement Work Practices. All this information was collected through several interviews with the plant management team. We used a specially-designed field research protocol to collect the data on the adoption of Lean Operations and High Involvement Work Practices in the production departments.

Our research protocol included four sections: 1) the adoption level of Lean Operations practices; 2) the adoption level of High Involvement Work Practices; 3) the adoption level of Lean Management Behaviors; 4) production department safety performance data (2008 and 2009).

We gathered additional data on control variables at the mini-factory and plant levels.

The first three sections of the research protocol were administered as a survey (lasting approximately 45 minutes) to two respondents: the plant manager and the production department manager. Our intention in assessing the same variables provided by two respondents was to avoid common method bias (Podsakoff et al., 2003). In this way, we were also able to control for biases deriving from self-assessment.

Measures

Dependent variable

Safety (t). Number of lost-time injuries which occurred at the mini-factory level in the year 2009. These are the occupational injuries that resulted in one or more days of inactivity away from work (Barling et al., 2003; Kaminski, 2001). The measure is readapted from Kaminski (2001) to match the one used by the firm as a safety performance parameter according to the industry standards.

Independent variables

Lean Operations Practices. Degree of adoption of Lean Operations Practices as conceptualized and captured by Ward and Shah (2007) Internal Lean Production Dimensions. External dimensions are excluded because the focus of our study is occupational safety in production. Ward and Shah's (2007) survey items were adapted to the tyre industry through extensive conversations with expert informants from the plants under investigation. We created an Additive Index of the standardized average of the evaluations of the plant director and mini-factory manager on 11 items. We chose the additive aggregation criterion considering that additive indexes represent a conservative estimate of the interrelated effect of the variables in question (Batt, 2002). A detailed description of the measures, scaling and reliability analysis is reported in Table 1.

Insert Table 1 about here

High Involvement Work Practices. Degree of adoption of the Employee Involvement practices. We used measures developed by Ward and Shah (2007) and Jiang, Lepak, Hu and Baer (2012), adapting them to the industrial setting under investigation after extensive conversations with key informants from the company. We created an Additive Index of the standardized average of the evaluations of the plant director and mini-factory manager on 4 items. See Table 2 for a detailed description of the measures, scaling and reliability analysis.

Insert Table 2 about here

Capability Development. Degree of adoption of the management behavior “workers' capability development”, as defined by and adapted from Womack (2011), Liker (2004) and Spear (2004). This variable is measured as the standardized average of the evaluations of the plant director and mini-factory manager on 1 item. A detailed description of the measures and scales is reported in Table 3.

Empowerment. Degree of adoption of the management behavior “empowerment of workers in the development of their own working standards”. This measure, adapted from Barling and colleagues (2003) on the basis of Adler (1993) and Adler and Borys (1996), is the standardized average of the evaluation of the plant director and the mini-factory manager on 1 item. See Table 3 for a detailed report of the measures and scales utilized.

Insert Table 3 about here

Control variables

Table 4 presents an extensive description of the control variables used in this study.

Mini-factory. This variable is built considering the cross-mini-factory differences attributable to variation in the technology used, the degree of processes automation and the nature of working activities. We built four dummy variables to measure the mini-factory effect: Banbury, Semi-finishing, Building, Curing.

Plant Age. This variable is adapted from Shah and Ward (2003) and represents an extension of their classification of three age groups.

Product Mix. This variable, adapted from MacDuffie (1995), measures the plant's product variety, which depends on the number of market segments served: Consumers (Cars, Motorcycles) and Industrial (Trucks, Agricultural Vehicles).

Safety (t-1). Number of lost-time injuries occurred at the mini-factory level in the year 2008.

Insert Table 4 about here

Model Specification

We tested our hypotheses using a Poisson Regression Model (Henderson and Cockburn, 1996; Neal and Griffin, 2006). Since our dependent variable was a count measure assuming non-negative integer values only, we assumed it had a Poisson-like distribution, in line with other studies in the field of occupational safety (Altree-Williams, 1990; Bailer et al., 1997; Glazner et al., 1999; Carrivick et al., 2003; Neal and Griffin, 2006). Indeed, accidents are low-frequency events usually resulting from unintentional mistakes (Neal and Griffin, 2006). In order to account for possible over- and under-dispersion biases, we also ran a negative binomial estimation model as a robustness check (Henderson and Cockburn, 1996; Miaou, 1994; Poch and Mannering, 1996).

RESULTS

Table 5 shows the descriptive statistics and the correlation matrix of the measures we used in our study.

Insert Table 5 about here

Table 6 provides the results of the Poisson Regression Model. As expected, the degree of adoption of Lean Operations Practices is significantly negatively related to the number of accidents. Hence, Hypothesis 1 is fully supported. At the mean, the elasticity of the number of accidents to the implementation of bundled Lean Operations Practices is -0.66. The degree of adoption of High Involvement Work Practices is also significantly negatively related to accidents in Model 3. For the average mini-factory, one additional point in the adoption of High Involvement Work Practices has a marginal effect size of -0.40 on the number of accidents. However, the coefficient loses significance in Model 4, hence only partial support can be claimed for Hypothesis 2. Both of the management behaviors we considered (capability development and empowerment) show a negative and significant association with accidents. Consequently, Hypotheses 3 and 4 are fully supported. At the mean mini-factory, as regards safety, the marginal effect size of a one-point increase on the agreement scale on the adoption of capability development behaviors is -2.16. The marginal effect, at the mean, of a one-point increase in the implementation of workers' empowerment in developing work standards is -4.58. The size of this result is particularly significant: an increase of 2.5 on the implementation scale reduces the number of accidents by one standard deviation. Hypothesis 5 is partially supported. Empowering behaviors significantly and positively moderate the relationship between Lean Operations Practices and occupational safety, with a marginal effect size, of the interaction at the mean mini-factory, of -1.17. On the contrary, we do not find support for the moderation effect of capability development. Figure 2 summarizes the estimated effects of the theoretical model.

Insert Figure 2 about here

Among the control variables, as expected, the number of accidents in the previous year is significantly and positively related to that of the current year. Model 4 in Table 6 shows that the age of the plant is significantly and negatively related to accidents. This result is somewhat unexpected and counterintuitive since older equipment is generally more dangerous. However, one possible explanation may be that in newer plants workers might be less experienced, knowledgeable and skilled; alternatively, older equipment commands greater attention of management to safety issues. Model 4 in Table 6 also shows that the dummy variables corresponding to Banbury and Semi-finishing are, as expected, significantly and positively related to the number of accidents. This finding is grounded on the fact that in these two production departments the equipment is more complex to maintain and requires more intensive material handling. A negative significant association is instead found between the dummy variable Curing and accidents. This was expected since Curing is one of the least labor-intensive production departments.

Insert Table 6 about here

Table 7 shows the estimation of the Negative Binomial Regression Model. The regression results, which we use as a robustness check, confirm the findings of the Poisson estimation.

Insert Table 7 about here

DISCUSSION

Our theoretical model of the safety performance effects of Lean Production is grounded on a wider, integrated view of the latter, which includes not only Lean Operations and High Involvement Work Practices, but also management behaviors. This model provides a better understanding of the extent to which the implementation of Lean Production positively affects occupational safety, and the conditions in which this occurs. Our work suggests a new potential avenue of research bridging Lean Operations, social sustainability and ethical leadership.

We posit that deeper and more comprehensive implementations of Lean Operations and High Involvement Work Practices positively impact workers' safety. Furthermore, we assert that a similar effect exists when production managers empower workers and develop their capabilities. We test this model using an operationalization of the internal dimensions of Lean Production systems described by Shah and Ward (2003, 2007). In addition, we explore the interactions between these dimensions and two management behaviors that, according to the Lean Leadership literature, characterize effective Lean Production environments. Interestingly, these two management behaviors (workers' empowerment and capability development) also clearly corroborate studies on what type of leadership is needed to foster the human side of organizational sustainability and to support socially sustainable operations.

Our empirical findings generally support the model and hypotheses, with Lean Operations and High Involvement Work Practices positively affecting occupational safety, especially when implemented along with empowering management behaviors. Our results indicate that workers are better off in terms of safety when: a) tools and routines for problem surfacing and continuous improvement are available (Womack et al., 1990); b) skills, motivation and opportunities are enhanced by High Involvement Human Resource Management practices (Jiang et al., 2012; Parker, 2003); c) managers coach and teach instead of simply commanding and controlling (Barling et al., 2003; Jiang et al., 2012; Liker and Ballè, 2013; Liker and Convis, 2012; Spear, 2004; Zacharatos et al., 2005); d) managers empower workers by granting them autonomy (decision rights) and participation rights over the development of their own work standards (Angelis et al., 2011; Parker, 2003). Interestingly, safety is even higher when Lean Operations practices are shored up by empowerment geared towards the self-determination of working standards (Adler, 1993).

Contributions and Future Research

This study of how Lean Production systems affect occupational safety offers several theoretical and empirical contributions.

First, our investigation frames the issue of occupational safety in production environments within the larger debate of organizational sustainability, emphasizing the importance of this specific though fundamental social performance dimension. Second, our study underscores the necessity to adopt a systemic view of how organizational practices might affect social outcomes, considering both production and work practices. Third, our work revisits management behaviors and leadership as constitutive aspects of this systemic view. In fact, we highlight how certain behaviors, largely referable to ethical leadership (caring and concern for others, altruism and the creation of a fair working environment) (Brown et al. 2006) directly affect occupational safety, improving it by positively interacting with Lean Operations practices. Fourth, we advance the specific stream of research linking HRM and sustainability outcomes. Beyond the usual attention to the environmental outcomes of these practices, this study highlights how a bundle, rather than just a single HR practice, could generate positive outcomes on the human side of sustainability (Dubois and Dubois, 2012; Pless et al., 2012; Taylor et al., 2012; Vidal-Salazar et al., 2012)

Fifth, our findings add to the well-established research on the effects of safety climate, orientation and leadership on safety outcomes. On the one hand, we highlight the practices that could most likely enforce a shared perception of safety (Bowen and Ostroff, 2004). In fact, we go beyond the "safety based on safety" and "safety based on ethics climate" explanations, suggesting how organizational practices (in our case Lean Operations and High Involvement Work Practices) might impact safety. On the other hand, we abandon the usual analysis of how leadership styles and/or traits in general affect safety. Instead we explore the effects of specific behaviors that are largely referable to ethical leadership, consistent with the practices under investigation and with the goal of promoting the human side of organizational sustainability.

We see this more focused and fine-grained approach as very promising, with potential for further developments. For example, an interesting direction for future research could build on Hart's (2009, 2013) distinction between motivations underlying the relationship between CSR and safety, which may be instrumental ('there is a business case for it') or normative ('it is the right thing to do'). The idea would be to test the effect on safety of more instrumentality-based versus more normative-based practices and behaviors.

In relation to this, our study could also contribute to assess the ethical impact of Lean Production. Indeed, the ethical value of Lean Production has been debated within ethics literature, stressing either its capacity to overcome the limitations of the rational organization, or the instrumentality of Lean Practices as regards company performance. Our manuscript could nurture this debate by providing a preliminary test of the ethical effects of Lean Practices (Hummels and de Leede, 2000; Raiborn and Payne, 1996), going so far as to embrace the overlooked perspective of workers autonomy and participation.

Finally, we bridge lean, behavioral and sustainable operations. Recently, the practitioner-oriented literature has dedicated increasing attention to the role of management in Lean Production Systems. More specifically, focus has centered on the management behaviors that might better support the successful adoption of a set of Lean Operations Practices (Mann, 2009; Rother, 2009; Shook, 2008), as well as the competencies, leadership traits and behaviors of managers in Lean Environments (Byrne, 2012; Emiliani, 1998, 2003; Liker, 2004; Liker and Ballé, 2013; Liker and Convis, 2012; Liker and Hoseus, 2008; Linderman et al., 2010; Mann, 2009; Rother, 2009; Womack, 2011). This increasing attention has curiously gone hand in hand with the rise of behavioral operations management research (Bendoly et al., 2010; Gino and Pisano, 2008; Loch, 2007), which questions the traditional rational behavior assumption about human beings participating in operating systems. The premise is that people's behaviors in all operations, including Lean Production Environments, are shaped by cognitive and emotional factors (such as heuristics, biases and overconfidence in judgment and decision making, social preferences in motivation, cultural norms in commitment and behavioral change). If this is the case, managers' actions might influence the way production systems work as well as how people perform and how they enact and apply Lean Operations Practices. Our study of how empowering and capability development behaviors adopted by production managers affect safety is but a first step in the direction of identifying, in a variety of settings, the management behaviors that might better serve the cause of improved safety and better working conditions.

Managerial Implications

From a practitioner's standpoint, we believe that the empirical evidence provided by this study clearly points to the necessity to adopt a systemic view of how Lean Production affects occupational safety. Indeed, as shown by our analysis of the size effects, significant improvement of occupational safety can be achieved by combining a wide and diverse set of practices.

Furthermore, specific management behaviors might also positively affect safety and interact with the other dimensions of Lean Production systems. As highlighted in the next section addressing the study's limitations, unfortunately our data do not allow us to test the joint effects on safety as well as productivity and quality. Nonetheless, we do believe that this broader approach would mitigate, if not eliminate, the often assumed trade-off between productivity and safety in manufacturing (Pagell et al., 2013).

Beyond working on these production practices, our research suggests that managerial decision making needs to consider the people management configuration that places the highest value on those HR practices oriented toward enforcing commitment, motivation and involvement. Our research shows the power of practices enhancing employee involvement, participation and multi-skilling in creating a safer work environment. In addition, our findings point out a new and important role for the HR function in terms of enforcing sustainability. People management practices have not yet found a defined role, but as far as environmental issues. Our study shows that, in order to improve the 'human' side of organizational sustainability, companies could focus on opening up channels to encourage a dialogue with employees and to provide them with opportunities to grow and to be exposed to a variety of experiences.

Finally, our study suggests that managerial behaviors need to be more directly oriented toward improving occupational safety, specifically targeting this aim. Empowering and capability development behaviors (and possibly others as well), not only support Lean Operations, but also represent the tangible sign that managers care about workers and want them to operate in a fair working environment. This implies a certain urgency for companies that strive to ensure employees' health and well-being, in working on more complex production and management systems, comprising a wide set of appropriate production and people practices and leadership behaviors.

Limitations

Our study suffers from several limitations. First, the sample size is small and the data was collected on a single firm from a specific industry. Although we believe that the single-firm approach (Bartel et al., 2004) and the history of the company under analysis are well-suited to the purpose of this study, the generalizability and robustness of our results need to be significantly improved. Testing the model longitudinally with panel data (trying to make causal inferences that are not possible with our data), possibly with a larger longitudinal sample including multiple firms, and even extending the study to other industries, are all potential steps in this direction.

Second, our measure of safety is objective and widely adopted in the literature on occupational safety (Barling et al., 2003; Neal and Griffin, 2006; Zacharatos et al., 2005). Nonetheless, future research should include other safety-related measures (e.g. near misses, behavioral-based safety indicators, etc.) or other "social performance" measures such as employee satisfaction, well-being, safety climate, safety culture and safety personal orientation and perceptions (Longoni et al., 2013; Pagell et al., 2013; Veltri et al., 2013; Zacharatos et al., 2005). Finally, including operations performance measures such as productivity and quality, further research could be conducted in the area of lean, behavioral and sustainable operations regarding the trade-offs or complementarities between productivity and safety (Pagell et al., 2013).

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FIGURE 1

Theoretical Model

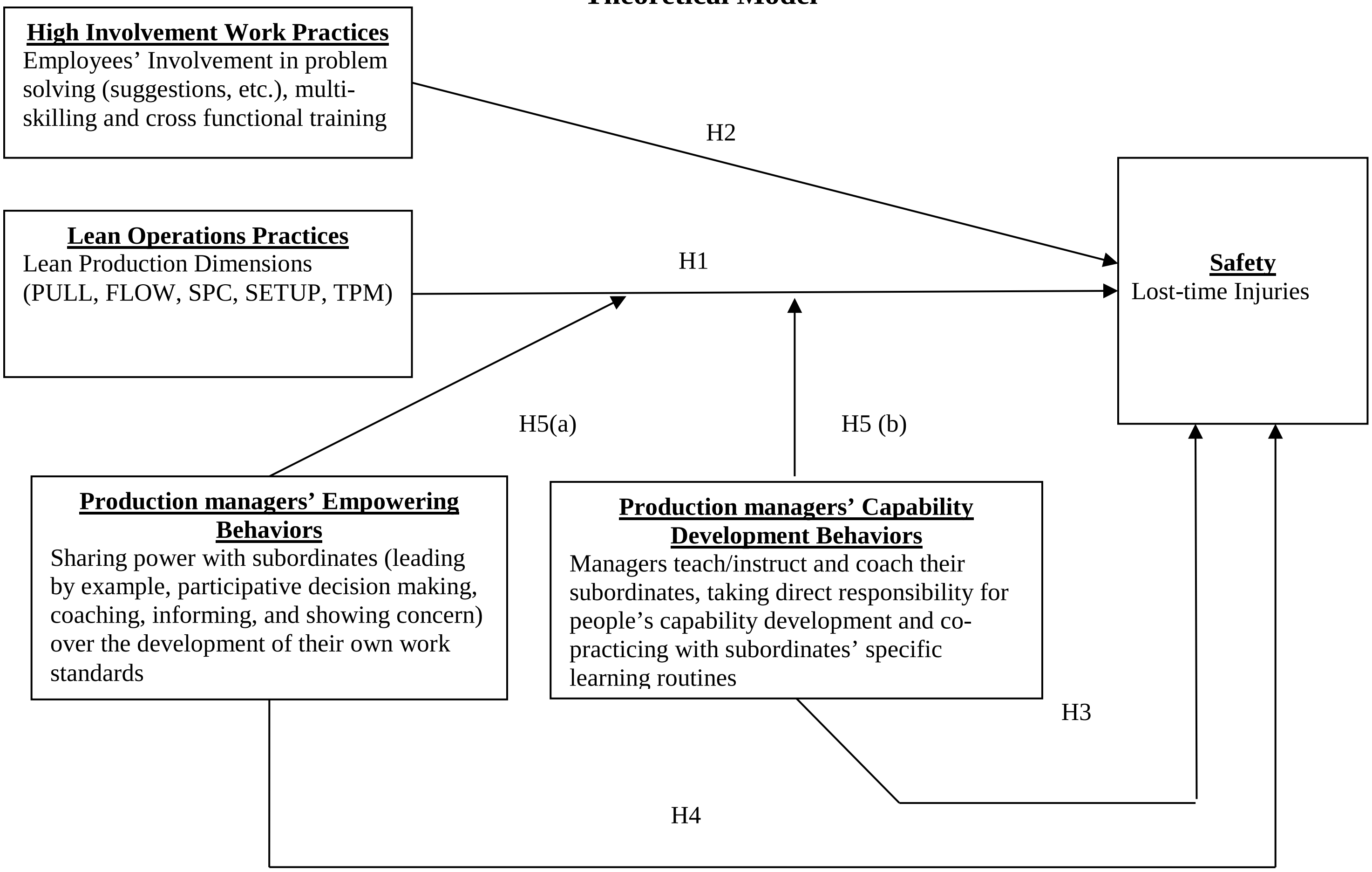

FIGURE 2

Estimated Effects of Lean Operations and High Involvement Work Practices on Safety

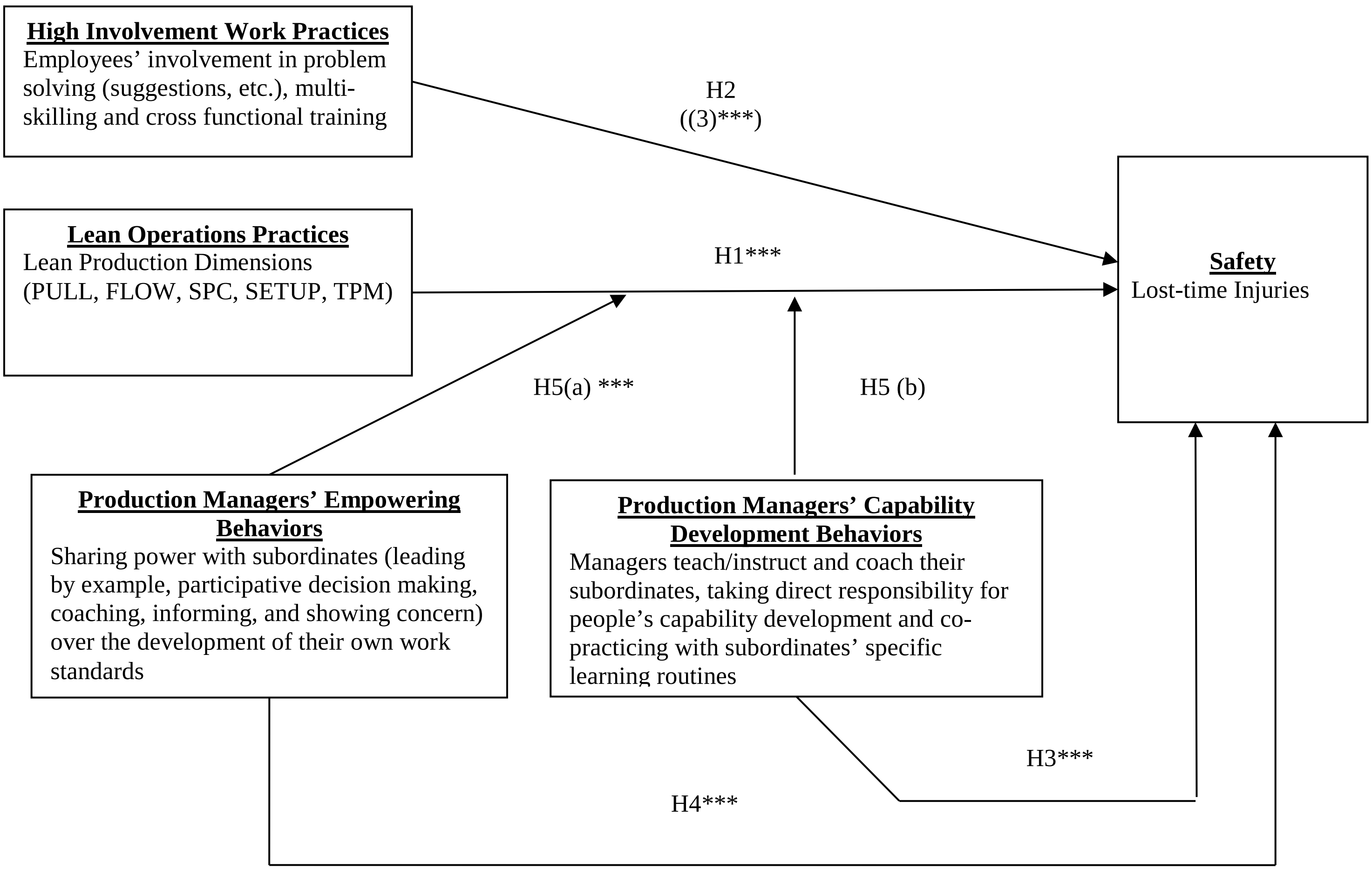

TABLE 1

Lean Operations Practices

Variable Name	Questionnaire Items, Scales, and Reliability Analysis	Description
Lean Operations Practices	N = 11 (α = 0.80) 1-5 scale: "1= no implementation and 5= complete implementation"	1) PULL (pull): facilitate JIT production including kanban cards which serve as a signal to start or stop production. 3 Items: "In my mini-factory, there is a 'pull' production system"; "In my mini-factory, production at stations is 'pulled' by the current demand of the next station"; "In my mini-factory, people use Kanban, squares or containers of signals for production control". 2) FLOW (continuous flow): establish mechanisms that enable and ease the continuous flow of products. 1 Item: "In my mini-factory, equipment is grouped to produce a continuous flow of product materials". 3) SETUP (set up time reduction): reduce process downtime between product changeovers. 1 Item: "Workers practice setup to reduce the time required". 4) TPM (total productive/preventive maintenance): address equipment downtime through total productive maintenance and thus achieve a high level of equipment availability. 4 Items: "People dedicate a portion of everyday to planned equipment maintenance related activities"; "People maintain all equipment regularly"; "People post equipment maintenance records on shop floor for active sharing with employees"; "People maintain excellent records of all equipment maintenance related activities". 5) SPC (statistical process control): ensure each process will supply defect-free units to subsequent process. 2 Items: "Charts showing defect rate are used as tools on the shop floor"; "People use fishbone-type diagrams to identify causes of quality problems".

TABLE 2

High Involvement Work Practices

Variable Name	Questionnaire Items, Scales, and Reliability Analysis	Description
High Involvement Work Practices	N = 4 (α = 0.84) 1-5 scale: “1= no adoption and 5= complete adoption”	1) “Workers frequently offer production-related suggestions”; 2) “Workers are involved in formal or informal problem-solving activities”; 3) “Production-related suggestions from workers are implemented”; 4) “Job rotation is frequent”.

TABLE 3

Capability Development and Empowerment

Variable Name	Questionnaire Items, Scales, and Reliability Analysis	Description
Capability Development	N = 1 1-5 scale: "1= strongly disagree and 5= strongly agree"	"Workers are primarily taught and developed by line managers through on-the-job learning and self-discovery".
Empowerment	N = 1 1-5 scale: "1= no implementation and 5= complete implementation"	"Team leaders help workers develop their own standards, sometimes requesting assistance from staff personnel (e.g. industrial engineering, quality)".

TABLE 4

Control Variables

Variable Name	Questionnaire Items, Scales, and Reliability Analysis	Description
Banbury	N=1 Binary Variable: 1=”Banbury” and 0=”Otherwise”	Mini-factory Type = Banbury. Finishing is used as the base variable.
Semi-finishing	N=1 Binary Variable: 1=”Semi-finishing” and 0=”Otherwise”	Mini-factory Type = Semi-finishing. Finishing is used as the base variable.
Building	N=1 Binary Variable: 1=”Building” and 0=”Otherwise”	Mini-factory Type = Building. Finishing is used as the base variable.
Curing	N=1 Binary Variable: 1=”Curing” and 0=”Otherwise”	Mini-factory Type = Curing. Finishing is used as the base variable.
Plant Age	N=1 1-5 scale: 1=”Early Age Plant” and 5=”Very Old Plant”	5-point scale that orders plants according to the age of machinery and equipment.
Product Mix	N=1 Binary Variable: 1=”Multi-Product Plant” and 0=”Otherwise”	1 when the plant covers both the consumer and the industrial segment, while 0 when just one of the two is covered.

TABLE 5

Descriptive Statistics and Correlation Matrix

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
(1) Safety (t)	9.80	11.39	0	61	1.00											
(2) Safety (t-1)	12.72	16.71	0	99	.97***	1.00										
(3) Banbury	.18	.39	0	1	-.13	-.17	1.00									
(4) Semi-finishing	.20	.40	0	1	.03	.01	-.23	1.00								
(5) Building	.20	.40	0	1	.22	.31	-.25	-.25	1.00							
(6) Curing	.20	.40	0	1	-.18	-.17	-.25	-.25	-.28	1.00						
(7) Product Mix	.36	.49	0	1	.11	.10	.02	-.15	.13	-.36*	1.00					
(8) Plant Age	4.02	1.06	2	5	.20	.22	.17	.10	.42*	-.78***	.06	1.00				
(9) Lean Operations Practices	28.27	5.14	22	37.67	-.13	-.04	-.02	.18	.03	-.09	.27	-.07	1.00			
(10) High Involvement Work Practices	14.62	1.88	10.5	18	.02	-.06	.12	.06	-.03	-.15	-.04	.29	-.07	1.00		
(11) Capability Development	3.19	0.62	2.5	4	.31	.44*	.11	.09	.06	-.16	-.02	.08	.19	-.38*	1.00	
(12) Empowerment	2.72	0.66	2	4	-.01	.120	.20	-.12	.13	-.01	.08	-.17	.45*	-.63***	.63***	1.00

* p<0.05 ** p<0.01

TABLE 6

Poisson Regression Model

Variables	(1) Safety (t)	(2) Safety (t)	(3) Safety (t)	(4) Safety (t)
Lean Operations Practices		-.05*** (.02)	-.03* (.02)	-.10*** (.02)
High Involvement Work (HR) Practices			-.05*** (.02)	.04 (.02)
Empowerment			-.31* (.17)	-.67*** (.15)
Capability Development			-.34*** (.11)	-.31*** (.07)
Safety (t-1)	.03*** (.00)	.03*** (.00)	.05*** (.00)	.05*** (.00)
Plant Age	-.08 (.13)	-.12 (.12)	-.23* (.13)	-.25*** (.06)
Banbury	-.30 (.29)	-.00 (.26)	.24 (.19)	.35*** (.10)
Semi-finishing	-.16 (.21)	.03 (.20)	.00 (.16)	.22** (.11)
Building	-.61* (.23)	.38** (.19)	-.43* (.24)	-.04 (.11)
Curing	-.55 (.38)	-.54 (.34)	-.79*** (.30)	-.57*** (.20)
Product Mix	-.39 (.25)	-.23 (.22)	-.35** (.16)	-.00 (.07)
Lean Operations Practices X Empowerment				-.17*** (.03)
Lean Operations Practices X Capability Development				-.03 (.02)
Constant	2.36*** (.66)	2.43*** (.65)	2.50*** (.56)	2.29*** (.33)
Pseudo R2	.51	.59	.63	.70

robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 7

Negative Binomial Regression Model

	(1)	(2)	(3)	(4)
Variables	**Safety (t)**	**Safety (t)**	**Safety (t)**	**Safety (t)**
Lean Operations Practices		-.05***	-.03*	-.10***
		(.02)	(.02)	(.02)
High Involvement Work (HR) Practices			-.05***	.04
			(.02)	(.02)
Empowerment			-.31*	-.67***
			(.17)	(.15)
Capability Development			-.34***	-.31***
			(.11)	(.07)
Safety (t-1)	.04***	.04***	.05***	.05***
	(.01)	(.00)	(.00)	(.00)
Plant Age	-.03	-.12	-.23*	-.25***
	(.11)	(.14)	(.13)	(.06)
Banbury	-.17	.01	.24	.35***
	(.33)	(.28)	(.19)	(.10)
Semi-finishing	-.03	.05	.01	.22**
	(.24)	(.23)	(.16)	(.11)
Building	-.48*	-.41*	-.43*	-.04
	(.25)	(.21)	(.24)	(.11)
Curing	-.29	-.49	-.79***	-.57***
	(.36)	(.37)	(.30)	(.20)
Product Mix	-.21	-.18	-.35**	-.01
	(.25)	(.21)	(.16)	(.07)
Lean Operations Practices X Empowerment				-.17***
				(.03)
Lean Operations Practices X Capability Development				-.03
				(0.02)
Constant	1.86***	2.33***	2.50***	2.29***
	(.66)	(.70)	(.56)	(.33)

robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

ABBREVIATIONS

JIT: Just in Time

SMED: Single Minute Exchange of Die

TPM: Total Productive Maintenance

SPC: Statistical Process Control

OEE: Overall Equipment Effectiveness

LEGEND