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*Publication date:*  
2013

*Document Version*  
Tidlig version også kaldet pre-print

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Kristensen, T. B., & Israelsen, P. (2013). The performance effect of the Lean package – a survey study using a structural equation model. Paper præsenteret ved Det Danske Ledelsesakademi konference, Odense, Danmark.

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# **The performance effect of the Lean package – a survey study using a structural equation model**

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## **Abstract**

**Purpose** - Our aim is to test and validate a system-wide approach using mediating relationships in a structural equation model in order to understand how the practices of Lean affect performance.

**Design/methodology/approach** – A cross-sectional survey with 200 responding companies indicating that they use Lean. This is analyzed in a structural equation model setting.

**Findings** - Previous quantitative research has shown mixed results for the performance of Lean because they have not addressed the system-wide mediating relations between Lean practices. We find that companies using a system-wide approach to Lean practices perform significantly better than those using a scattered array of these practices. This paper shows that the effect of Lean's flow production practices on performance is mediated by analytical continuous improvement empowerment practices, and by delegation of decision rights practices. Furthermore, the paper provides evidence that supports the view that actions of middle management enhance performance in the system-wide approach to Lean.

**Originality/value** - In contrast to previous surveys, our results support case studies describing the multiple interdependencies of Lean practices in creating improved performance. Hence, we develop a new system-wide structural equation model approach with multiple mediations, and we validate this with substantial tests.

Keywords: Lean, Package, Performance, System approach, Structural equation model

## **1. Introduction**

Lean, including Just-in-Time (JIT), is one of the popular management philosophies that inspire companies in terms of achieving sustainable profits. As pointed out by Fullerton and McWatters (2001), Just-in-Time is one of the practices that companies use when trying to improve their competitiveness. It is necessary,

therefore, to research whether or not the promising words of Lean actually help to enhance a company's performance.

Since Womack *et al.* (1991) published their seminal book on the Toyota production system, many companies around the world have adopted the methods in question. In their book, *The Machine That Changed the World*, Womack *et al.* (1991) published statistical results that showed how, according to a series of core business performance measures, the Japanese production method, especially production at Toyota, was superior to production methods in the contemporary American car industry. Toyota's production method has become widely dispersed throughout many parts of the world, including Scandinavia, under the label of Lean. Even though the techniques, methods, and mindsets of Lean have been well documented (e.g., Liker, 2004; Liker and Meier, 2006; Bicheno and Holweg, 2009), the performance effects for companies other than Toyota are still being questioned, or at least found difficult to assess, in case-based research and cross-sectional surveys. In this paper, we seek to understand how Lean practices can enhance performance by approaching them in a system-wide manner using a cross-sectional survey.

The remainder of the paper is structured as follows. Section 2 contains the theoretical background and develops the hypothesis. In Section 3, the research method is described, and, in Section 4, the analysis is presented. Section 5 presents the conclusion. Finally, in Section 6, we describe the limitations of our study and point to directions for future research.

## **2. Background and hypothesis development**

Several studies exploring the performance effects of various Lean practices (including Just-in-Time and World Class Manufacturing), which we present below, have led to mixed results. It is argued that these mixed results might very well be caused by the approach used in measuring the effects of the Lean package. Therefore, in our present survey and analyses, we have reviewed previously used methods and results and have generated a revised set of constructs and relations based upon this review.

### **2.1 The mixed performance effect of Lean in previous studies using different constructs**

Huson and Nanda (1995) discovered that JIT manufacturing, compared to non-JIT manufacturing, had mixed effects on different performance measures. While the unit cost rose and the operating margin per sales dollar declined, earnings and earnings per share still improved due to a mix of revenue increase and interest reduction caused by a decrease in working capital. A decrease in inventory was also found in Balakrishnan *et al.* (1996). The latter study, however, found no performance effect linked to JIT adoption when measured in terms of return on assets as the dependent variable and compared to that of firms in a control group. Both studies measured JIT adoption as a binary item, i.e., as being either present or not present. In contrast, Fullerton and McWatters (2002) measured Lean in terms of degree of implementation, not just as a binary variable, as omitting this variable may have caused the mixed result in the two papers just mentioned. Another study, by Kinney and Wempe (2002), found that adopting JIT – again measured only as a binary

variable – had a positive effect on profit margin. However, the demonstrated effect was unsustainable, as the control firms leveled out the difference in five to six years.

Other studies employed a more detailed approach to measuring the construct of JIT/Lean in order to gain a better understanding of the complexity of these manufacturing strategies. A case-based survey, carried out by Young and Selto (1993) within one large company, revealed no performance effect on six different items measuring performance. In their study, the gaps in terms of what is supposed to be done and what is actually being done in relation to different JIT elements were hypothesized with a view to explaining the evident variations among different workgroups. Unfortunately, they were not able to demonstrate any significant results. The included elements of JIT were weekly scheduling, care for waste, immediate shipping, statistical process control, continuous improvement, shop floor layout, and being able to see co-workers. Furthermore, the study also included constructs representing “the ability to solve shop floor problems,” “teamwork attitude,” “total quality control,” and “information gap and understanding.” These constructs and items have inspired the Lean practices we have chosen to include in our study as expressed in Table 1. However, unlike Young and Selto (1993), our study is not focused on the implementation level, but on how the various practices of Lean work together.

If the underlying reason for the lack of results of JIT/Lean is not to be found in implementation obstacles, then perhaps it is to be found amongst the findings of another recent cross-sectional study, i.e., that of Banker *et al.* (2008). Here, it was shown that within World Class Manufacturing (WCM/Lean), a certain degree of performance effect can be explained by a simple construct that measures the degree of WCM. The degree of WCM is measured using six WCM tools to form a score anywhere between 0 and 6. Implicitly, it is assumed that the tools, or practices, of the manufacturing strategy work together additively. No matter which one of the six tools a company employs, it still scores one point on the 6-step scale. Implicitly, it also follows that it does not matter which combination of tools the responding companies employ. To our mind, this is too simple an approach to use in addressing the construct of WCM (or Lean), and to understanding why this manufacturing strategy actually gives rise to a real performance effect. In contrast, case studies carried out in relation to Toyota (e.g., Womack and Jones, 2003) and other Lean studies (Kennedy and Widener, 2008) call for a systems approach to understanding the performance effect of Lean practices and underscore the fact that these practices are not just piecemeal. The practices have to be combined as a packaged set of practices in order to demonstrate a sustainable performance effect. Hence, a system-wide approach is adopted in this paper.

Fullerton and McWatters (2001) used a combined JIT construct that consists of the average score of three JIT factors. As a result, their construct does not ensure that high scoring JIT companies use enough practices from each of the three JIT dimensions/factors. For example, the combined JIT measure may categorize a company that scores very high on one factor and low on another as a high level adopter, while in actual fact the company in question does not possess a balanced and complete JIT package. Nevertheless, Fullerton and McWatters (2001) did find significant performance effects, which underline the need to address JIT, or Lean,

as a multidimensional phenomenon. Their three factors consisted of JIT-manufacturing, JIT-quality, and JIT-unique, where the latter expresses Kanban and JIT purchasing (see below for a discussion of these).

Shah and Ward (2003) utilized the concept of complementarities (their label) between Lean practices. In their study, they categorized practices in terms of four bundles, i.e., Total Quality Management, Total Productive Maintenance, Just-in-Time, and Human Resource Management (TQM, TPM, JIT, and HRM). Each of these bundles has a performance effect on both unit costs and non-financial measures. Thus, to our mind, the approach used in this study appears to be the most compelling amongst current studies of Lean practices, equaled only by that of Fullerton and McWatters (2001). Therefore, we will also be harnessing the concept of bundles of practices in our approach to understanding how Lean practices contribute to performance. Before delving deeper into the perception of Lean as a package and other aspects that may explain its performance effects, it is necessary to understand the particular nature of the individual Lean practices.

## **2.2 The individual Lean practices**

Lean consists of a package of practices, such as principles of governing a company by delegating decision making, the use of flow techniques in the processes, and analytical tools to sustain continuous improvement. In the present study, we have chosen to include 12 practices for measuring the Lean package, cf. table 1. These practices constitute the main practices within Lean. While according to Bicheno and Holweg (2009) and Liker (2004), these 12 practices are not the only Lean practices, to our mind they constitute the main components of Lean.

In the following, we provide a brief account of the 12 practices.

*< Insert Table 1 about here >*

U-cell production consists of the basic shop floor layout of the Lean organization. This means that the workstation, machinery, or labor set-up is shaped like the letter U (Liker, 2004). This ensures the shortest distance between stations, which makes it easier for co-workers to help one another and for individual workers to manage more machines simultaneously. A U-cell production requires more than just having a U-shaped shop floor layout, it also requires the identification of product families with almost the same production flow (Bicheno and Holweg, 2009). Kennedy and Widener's (2008) case study provides a good example of how such an organization is divided into product families, each of which has a dedicated cell connected. This way, flow is optimized and queuing in front of functional monuments (i.e., resources shared by more product families) is reduced. In addition, the fact that cell members function as a team is a prerequisite of a U-cell production set-up.

Kanban is both a visual management system related to the work in progress and a pull system for the production flow (Liker 2004). In short, it works as a signal device system whereby a given process calls for products or parts from other production processes (Bicheno and Holweg, 2009). The feeder processes will not start producing until they receive a Kanban card from a downstream process. Together with U-cells, this

provides a visual system of the current demand and inventory levels, not to mention a layout whereby it is easy to see which processes are not working optimally and hence are falling behind. Furthermore, this organizational layout and visual device forces the production cells to maintain a certain flow level without stockpiling. It can easily be combined with 5S.

5S consists of multiple techniques. Its objective is to keep the production cell clean and organized. The most important technique in 5S is the standardization practice known as “standard work” (Bicheno and Holweg, 2009). The standard work measure provides the foundation for improvements, as the standards constitute the baseline against which one can compare improvements (Liker, 2004; Liker and Meier, 2006). Furthermore, standard work also stabilizes the process, thereby providing the opportunity to easily recognize and correct abnormalities so they do not interrupt the production flow significantly. Standards are also important in terms of aligning actions with company goals (Kennedy and Widener, 2008).

Single-Minute Exchange of Die (SMED) is a practice that may be included when creating an organization that can deliver flow production. Single-Minute Exchange of Die consists of the systematic work involved in reducing changeover times, which, in turn, constitutes an important element in creating flow alongside small inventories (Bicheno and Holweg, 2009).

Total productive maintenance (TPM) is the last practice in the group of practices we label “flow production.” Total productive maintenance is about avoiding the breakdown of resources in order to create stability in terms of machine availability (Bicheno and Holweg, 2009). This is certainly necessary in order to stabilize and standardize production flow. It is impossible to create standard work norms in the event of numerous unplanned machine stops, as the required machine time is made uncertain.

Kaizen is a practice that aims to ensure sustainable continuous improvements (Liker, 2004), which are often achieved through events taking place on the shop floor. Kaizen events typically consist of measuring the current state of affairs during the first days/weeks. The current performance measures are subsequently analyzed and plans are made to define the objectives of the event in question. The event is then carried out and its results are measured concurrently. This process is repeated a number of times in order to ensure that the results are sustainable (Bicheno and Holweg, 2009). In short, Kaizen is about providing employees with a somewhat standardized analytical tool to improve operations and thereby remove waste (Liker, 2004). The objective in this case is to enhance current operations by focusing measurement on some area of interest in order to acquire inspiration regarding possible avenues of improvement, then to carry them out, and subsequently to sustain them systematically. While Kaizen time is dedicated to helping employees enhance their knowledge, it also entails a standardized procedure that ensures that this knowledge becomes incorporated in daily work. Whiteboard meetings are somewhat similar to Kaizen events, as these meetings aim to ensure that all employees follow up on the production measures. Whiteboard meetings are typically carried out once a week in the case of shop floor employees, and more frequently in the case of foremen and middle managers (Carreira, 2005). These meetings usually take place in the middle of the production floor and consist of a few standard measures of how well operations are running. This way, they almost constitute a real time follow-up on the production problems and deviations that almost unavoidably crop up from time

to time. Employees are expected to engage actively with the figures and to present ideas for improvement based upon them.

Value stream mapping (VSM) is a core analytical tool of the Lean package of practices. Its purpose is to map all processes and categorize them as either value-added or non-value-added activities (cf. Rother and Shook, 1999). The resulting map, or VSM, shows how the production units flow through the processes, while also providing additional information regarding lead times, stock turns, changeover times, and cycle times.

Six Sigma has not been developed, nor is it employed under the name of Six Sigma, by Toyota. However, Toyota has built many of the Six Sigma elements into their quality improvement programs, so Six Sigma may still be considered part of the Lean program (Bicheno and Holweg, 2009). Six Sigma is a practice that aims to measure variability within processes by focusing on quality issues such as scrapped parts-per-million.

Essential to the Lean package approach is the involvement of every worker within the given organization (Lind, 2001), not in self-controlled groups, but rather in groups that have access to the help of their foremen to overcome problems using standards and methods set by top management. In fact, the decentralized decisions are dominated by a group agenda approach known as the enabling formalization (Ahrens and Chapman, 2004), which is a key element of Lean (Liker, 2004). The primary organizational structure of Lean consists of teams. This structure is necessary due to the high degree of interdependency in JIT organization where there are very few stocks to buffer problems that arise from lack of coordination or an isolated focus of responsibility. Still, it is left up to each team to reach decisions on a wide range of issues, with the help of the principles, practices, and philosophy formulated by top management. Similarly, the team employs the company's chosen tools to implement improvements (Liker, 2004). In other words, the teams possess a large degree of decision-making authority while at the same time being expected to follow company guidelines. Hence, they are labeled as partly self-controlled teams. The teams should be controlled by what customers want and must apply the basic methods used by the company (Huntzinger, 2007). Teams must have specific purposes and, subject to specific constraints, contribute to the implementation of Lean practices.

Policy deployment is a practice whereby consensus within the organization is built up. The key idea here is that it is better to reach less optimal solutions by means of consensus than to have perfectly optimal solutions imposed by a technocratic expert regime. The objective is to inculcate commitment to company goals amongst all employees by communicating a set of common goals. This is mainly achieved with the help of very short reports in A3 paper format and by participation in the organization. All stakeholders in a decision are involved through participation, and those who have to implement the decision also have a strong influence on the design of the plan. It is not just a plan of the outcomes, but also of the means, and these have to be aligned with the rest of the organization (Bicheno and Holweg, 2009). Policy deployment involves a long process in order to bring about consensus; however, decisions can subsequently be implemented rapidly.

Policy deployment is thus similar to the partly self-controlled teams mentioned above, as both practices delegate decision-making rights or influence to lower organizational levels, and in both cases, this occurs via a group agenda in a controlled manner. The workers/employees co-influence on their own tasks and processes is added as the last practice of delegation of decision rights.

### **2.3 Grouping the constructs of Lean in a system**

Lean is a practice-defined variable, which means that it is constituted in practice by practitioners. In this case, the empirical ideal is taken from Toyota. In order to research a practice-defined variable, it is often necessary to break it down into several even more narrowly defined variables. This is certainly the case with Lean, as it consists of many methods and techniques that must be applied in a certain manner if they are to have the desired effect. Therefore, many companies choose only to work with parts of Lean, i.e., they only pick certain elements to implement. They do this for several reasons, taking into account, for example, that they entail different production environments from that of Toyota, or that they only want a light version of Lean in order to ensure rapid implementation. Bearing in mind that Lean is a long-term strategy, the actors may choose only some parts of Lean to optimize their organization in order to produce short-term results. The inherent risk of this approach lies in the fact that one must first of all separate out all the elements known from the Toyota production system before picking one's preferred element(s) of interest, and then make sure to use only these as a new package. This new package is not identical to that tested over many years and proven successful at Toyota. Hence, it may not be a coherent system. It should, however, also be emphasized that Toyota has worked with their model for many years and that it takes many years to become sustainably profitable through the implementation of Lean (Liker and Meier, 2006). In this way, the Toyota production system is a practice-defined variable, which in turn is giving rise to new practice variables for other companies as they choose and combine practices in a manner different from that of Toyota.

Taiichi Ohno, inventor of the Toyota production system, pointed to the fact that the key to the Toyota production system is not any of the individual elements, but all of the elements together as a system (Liker, 2004). Liker and Meier (2006) warned against perceiving Lean systems as piecemeal technical projects. This will only provide the organization with an incentive to pick low hanging fruits, thereby missing the chance to acquire a long-term sustainable system. Another central study of Toyota reflects upon Lean as a package (Kobayashi, 1995). In this study, the argument is that the Lean system can only work if all the pillars of the system are functioning, and if a cross-functional system has evolved between the pillars.

Following on from this, the Shah and Ward (2003) study pointed to some of the complementarities existing between the practices within each of their proposed four bundles of practices. While validating the bundles by means of factor analysis, which confirms their existence, they did not provide evidence of an interaction effect between the four bundles, and they did not find any synergy between the bundles. Each of the four bundles has a main effect on performance in the same regression model. However, Shah and Ward (2003) did not determine whether or not there is an interaction effect between the practices within each bundle. Moreover, Shah and Ward did not research any mediator effects between the bundles. Therefore, the Shah and Ward (2003) study seems to have supported the additive effect of practices rather than the dependencies between the bundles of practices. Nevertheless, with the help of factor analysis, their study confirms that



practices are used in bundles, a fact that seems to suggest that the responding companies realized that practices have to be used in bundles and cannot function on their own as individual practices.

Shah and Ward's (2003) support of additive effects stands in contrast to the findings of the above-mentioned case studies of Lean at Toyota. With a view to obtaining a deeper understanding of the system-wide approach mentioned above, we have coined our three main constructs in a manner different from that of Shah and Ward (2003). Their HRM bundle consisted of self-directed teams and a cross-trained workforce, the latter of which entails a mix of capabilities from training and decision delegation. Furthermore, the practice of "competitive benchmarking" is factor loading on more than one bundle of practices, which reflects the need to separate information empowerment from delegation empowerment, as the content of these two entities is substantially different. In fact, they constitute two constructs that complement one another, as the delegation of decision-making rights would not be effective without supplying the delegated employees with support information in the form of analytical tools such as value stream mapping (VSM), on which they can base their decisions. Even though VSM is the key analytical tool of Lean, it is not included in Shah and Ward (2003), as information empowerment is almost absent from their study.

Shah and Wards (2003) JIT bundle consists of production flow techniques, of which our main construct "flow production" is a condensed version. The TPM bundle in Shah and Ward (2003) is also included in our flow production construct, as TPM is a practice that aims to decrease unplanned downtime on resources, which is a key element of getting production to flow. Having a planned preventive maintenance strategy is similar to standardizing processes, which is part of 5S. Similarly, if process times vary due to unplanned down time, Kanban would not be applicable, as running a JIT factory requires certainty in terms of capacity availability. Additionally, the TQM bundle is not included as a separate construct in our three main constructs. However, we have included Six Sigma and Kaizen in the analytical continuous information empowerment construct, as both of them are somewhat standardized methods of gaining information on the performance measurements.

Looking more closely into the study of Fullerton and McWatters (2001) we find that it fails to focus on the importance of including the HRM-bundle elements, i.e., self-directed teams and the delegation process. Also, unfortunately, they focus narrowly on the tangible elements of the Lean package, the elements we mainly categorize as flow production in our model. Thus, they do not address the need to empower workers with both information and decision rights if an organization is to ensure that its flow techniques function optimally.

Shah and Ward (2007) added to the explanation of why organizations with a complete Lean package implementation perform better than organizations with a more piecemeal approach. They argued that it is because complete implementation is more difficult for competitors to imitate. Hence, these organizations have a competitive advantage that is difficult to copy. Moreover, Shah and Ward (2007) recognized the need to understand enhanced performance effects from Lean as an effect where the practices are mutually dependent.

Furlan *et al.* (2011) built upon bundles similar to Shah and Ward's (2003), and they actually found a complementary effect between three of the bundles on performance. The three bundles they included were JIT, TQM, and HRM. Their tests presented a complementary effect between the bundles using a multiplicative interaction of the bundles showing that HRM magnifies the performance effect of the other bundles. Their study was definitely a step in the right direction towards understanding Lean as a system, as they showed that practices depend on each other. This represents one approach to perceiving Lean as a system. Nevertheless, we believe that their model and tests have some weaknesses. Firstly, the model excluded TPM, even though it was built on Shah and Ward's (2003), where it was included. Secondly, the model measured the three bundles as binary variables, which is quite reductionist, while keeping in mind that Lean is a complex system; this was also acknowledged as a limitation of the study by the authors themselves. Thirdly, the study used a moderation model approach, where it demonstrated that HRM moderates the effect of JIT and TQM on performance. However, a moderator model fit approach requires the variables to be independent of each other (Luft and Shields, 2003), as the moderator variable only affects the relation of the independent variables on performance. Hence, the moderator variable is not affected by the other independent variables. This assumption of independence violates our system-wide approach to Lean, as doing one Lean practice would affect the company's choice of doing more of another Lean practice. We elaborate on this in the hypothesis development section. When the use of one Lean practice affects the choice of doing another in order to obtain enhanced performance, the independence assumption of the moderator is violated, and a mediator approach is more appropriate. This can be achieved in a structural equation model with multiple mediator relationships (Kline, 2005), which we apply in our test section. Moreover, it is difficult to use moderator models of fit when there are more than three variables, as this requires higher-order multiplicative interaction terms that are often difficult to interpret (Venkatraman, 1989).

The mixed results that have been reached when measuring the effects of Lean and JIT in the surveys examined above seem to be caused by a general lack of understanding of the complexity of the dependencies between the individual practices that qualitative studies of Toyota have called for. This leads to our system-wide model for understanding how Lean as a package can improve performance. This model is presented in Figure 1. Each of the relations in the figure forms a part of our hypotheses. Thus, Figure 1 represents the total of our hypotheses collected in one system.

*< Insert Figure 1 about here >*

Each of the relations (hypotheses) in Figure 1 is described below:

**Hypothesis 1a:** Flow production is positively associated with delegation of decision rights.

**Hypothesis 1b:** Flow production is positively associated with continuous improvement founded in analytical information empowerment.

Moreover, the direct relation between "flow production" and "performance" is tested to verify that this should not be significant. This relation is not one of the formulated hypotheses, and the reason for this should

be found in the formulation of hypothesis 1a and 1b. In fact, this non-relation between flow production and performance proves that Lean is a system-wide practice package, where no single element can affect performance additively as a main effect in a regression analysis (like Shah and Ward (2003) presented it). This non-relation is a novelty of this paper. On the contrary, we hypothesize that the effect of flow production on performance is mediated by “analytical continuous improvement” and by “delegation of decision rights.” The effect on performance “caused” by flow production is thus indirect. It is dependent on hypothesis 1a, 1b, and 4a, 4b, as these represent the paths from flow production to performance, crossing the other two variables. We label this mediation relation **Hypothesis 1c**.

**Hypothesis 2:** Continuous improvement found in analytical information empowerment is positively associated with delegation of decision rights.

**Hypothesis 3a:** Middle management behavior is positively related to continuous improvement founded in analytical information empowerment.

**Hypothesis 3b:** Middle management behavior is positively related to performance.

**Hypothesis 4a:** Delegation of decision rights is positively associated with performance.

**Hypothesis 4b:** Continuous improvement found in analytical information empowerment is positively associated with performance.

These hypotheses reveal that we expect to find that performance is significantly improved when companies employ flow production practices mediated by information empowerment so that actors, at the level of action, can reach well-informed decisions. In order to complement/facilitate this, it is necessary to delegate decision-making rights. Hence, performance is not directly affected by flow production. Moreover, if middle management encourages Lean behavior, this leads to improved performance both directly and through the use of analytical continuous improvement practices. This short explanation sums up the system-wide model presented in Figure 1. The hypotheses are further developed and explained in the next section. Overall, this should give a more comprehensive and coherent understanding of how Lean affects performance.

## **2.4 Further explanation and elaboration of the hypotheses**

In Figure 1, we hypothesize that the effect of flow production on performance is mediated by analytical continuous improvement (CI) and by delegation of decision rights. Analytical continuous improvement and delegated decision rights are needed in flow production in order to facilitate a quick response to the problems that inevitably occur within flow production systems having only low levels of stocks to buffer against such problems (Kalagnanam and Lindsay, 1998; Selto *et al.*, 1995). If the production flow practices are to create a sustainable level of good performance, it is necessary to delegate decisions on how to handle potential problems in order to create local ownership for these decisions on the shop-floor level, and the decision-

makers need to be supported by well-functioning, timely information regarding process performance (Lind, 2001; Kalagnanam and Lindsay, 1998). This proposition is similar to Galbraith's (1973), who believed that one viable strategy for coping with uncertainty (caused by lower stocks and a higher pace in flow production, etc.) is to enhance the decision makers' information processing capability by providing more sophisticated information systems. The latter, in our case, are the analytical continuous improvement practices. Gerdin (2005) confirmed that adoption of JIT increases uncertainty. A part of the analytical continuous improvement construct is about monitoring process and output measures. This is, for example, an integrated part of whiteboard meetings (Parry and Furner, 2006). This monitoring is critical to signal when adjustments to operations need to be made (Parry and Furner, 2006). The level of adjustments increases as flow production increases. Thus, flow production needs to have a good monitoring system to back it up, and this is shown by our mediator-relation in hypothesis 1a, rather than by a direct relation from flow production to performance.

The need for a good monitoring system is further supported by the claim that JIT companies should increase their reliance on nonfinancial information (Gerdin, 2005) because information systems must monitor, identify, and communicate the sources of delay, error, and waste in the system to decision makers (Atkinson *et al.*, 2001). It is important to notice that the delegation of decisions rights construct does not signal a complete and full decentralization. Policy deployment and partly (not fully) self-controlled teams both involve a substantial amount of teamwork. This teamwork is important in the uncertain environment of JIT/flow production to manage increased functional interdependencies (Abernethy and Lillis, 1995; Galbraith, 1994; Kalagnanam and Lindsay, 1998). This is represented by delegation of decision rights as a mediator of flow production on performance. In general, maintaining, sustaining, and benefitting from practices such as U-cells, Kanban, SMED, TPM, and 5S requires analytical continuous improvement, as these practices are not just one-off consulting implementations. They are continuously adjusted and calibrated to fit the condition of the customers and the environment (which is often dynamic for Lean companies) using analytical information, and this continuous process should preferably be decentralized to allow quick responses with local knowledge. Moreover, having updated standards in 5S will not improve performance significantly unless the standards are put under pressure for sustainable reduction continuously, with analytically derived solutions from decentralized decision makers. Johnson (1992) summed it up by describing business performance as achieved best by being responsive and flexible, and this requires use of real time problem solving to control lead times, variation, and customer satisfaction, which in turn requires training workers in self-management (also part of hypothesis 3a).

Hence the arguments above lead to our hypotheses 1a, 1b, 4a, 4b, and to some extent, also hypothesis 2. The latter hypothesis is further elaborated in the next paragraph.

Hypothesis 2 is further supported by Young and Selto (1993). They concluded that even though a measurement system may be well designed and strategically aligned, its effectiveness is diminished if it is not available on the shop floor where it can affect the operations decisions. Hence, shop floor workers and their team leaders should be able to make decisions, and these should be well-informed decisions. This requires the decision rights to be delegated through the use of, e.g., policy deployment and partly self-directed teams practices. Making decision-makers on the shop floor and lower level managers well informed comes from the use of analytical continuous improvement practices. Therefore, even though the analytical

continuous improvement practices (“measurement systems” as labeled by Selto *et al.*, 1995) may be implemented, their effect on performance is mediated by the delegation of decision rights construct. However, there is a direct relation, hypothesis 4b, between the analytical continuous improvement construct and performance because even though continuous improvements are driven from top management, there may be an effect on performance. We suspect, though, based on Young and Selto (1993), that this hypothesis 4b relation will not be as strong as hypothesis 2, and consequently also not as strong as hypothesis 4a.

It is important to understand that hypotheses 4a and 4b cannot be understood in isolation. Hence, even though these hypotheses are confirmed in the statistical tests, it cannot be concluded that analytical continuous improvement and delegation of decision rights will always positively affect performance. The use of these two constructs is affected by flow production. Thus, it is the mediating role of the first two mentioned constructs on flow’s effect on performance that is central in the system model. Hypotheses 1a, 1b, 4a, and 4b have to be understood and tested system-wide. Therefore, it is the collective understanding of these that we want to test. This is an ambitious approach because if the result of testing one of these hypotheses is non-significant, the validity of the other three hypotheses would be compromised. This is, in fact, a system approach that has not been modeled or tested previously in a Lean context. The elements of Lean cannot be studied as independent variables. Instead, we perceive that the choice of flow production affects the choice to use the other elements in the Lean system, as modeled in Figure 1.

Ouchi and McGuire (1975) came to the conclusion that personal controls are effective when the processes (means) are well known. In the Lean organization, the means are well known and a certain behavior is expected, i.e., that described by the practices of Lean. The Lean shop floor is also focused on visualizing problems and bottleneck situations with the aid of cell-layout and the practice of 5S. Furthermore, the middle and team managers are expected to spend a lot of time on the shop floor in order to detect problems and to rectify them immediately in cooperation with the team members (Lind, 2001). The implementation of Lean practices takes place where value is created, a fact that is known as “Gemba” in Toyota terminology (Bicheno and Holweg, 2009). Therefore, leaders control whether employees carry out the correct Lean behavior. Additionally, leaders train Lean practices themselves, thereby acting as behavioral role models on the shop floor. This “Lean management” feeds into the system of the other Lean practices, and the performance effect from this Lean management is mediated by the analytical continuous improvement empowerment variables. As explained above, this is because middle management assures that the shop floor workers are working according to “right” Lean behavior and thereby deploys Lean practices in a more correct manner. Put differently, though less ambitious, middle management is not reducing the practice of Lean to just an option, as they themselves are committed to Lean. This being the case leads to hypothesis 3a. Furthermore, if middle management is committed and encouraged to do more Lean – e.g., by wanting to train employees in Lean, be Lean role models, and follow up on employees’ Lean behavior – they would also encourage the organization to increase the use of analytical continuous improvement.

However, 3b hypothesizes a direct positive association between Lean management and performance. This is because our model only includes companies stating that they use Lean, i.e., they have indicated a need to operate in the Lean way and have a middle management that ensures and encourages Lean behavior, which

we expect will somehow affect performance. However, this latter relation is not suspected to be as strong as the one in hypothesis 3a.

### **3. Methodology**

In this section, we present our methodology. This includes survey design and sample, survey constructs, and choice of statistical technique.

#### **3.1 Survey design and sample**

The survey at hand is completed with the help of Danish Industry (DI), which is an organization for Danish employers. Most large Danish industrial companies are members of DI, as it is the largest and most influential organization of employers in Denmark. The distribution of DI members is representative of the general distribution of private companies across industrial sectors in Denmark.

A main advantage linked to using the DI membership database in mailing out the questionnaire is that we could ensure that our respondents are knowledgeable people by using their direct email address. Furthermore, follow-up emails were sent out to make sure that as many as possible answered. The questionnaire was distributed to 1,517 members, of whom 459 responded to the survey. This is a 30% response rate, which the authors find satisfactory, especially when taking the absolute number of respondents (459) into account, which is quite high in studies carried out among private sector companies.

The survey was mailed out in 2008 and completed that same year. Of our respondents, 16% were CEOs, 23% were department leaders, and 45% were production directors at the time. The remaining respondents had other titles. The sample is a so-called “convenient sample,” as the authors did not develop the research items (questionnaire), nor did we collect the data. The questionnaire and data collection was done by researchers at DI. However, the authors’ non-involvement in this part of the research does not affect our analysis or conclusions. Limitations are described in section 6.

We only use 200 of the 459 responses in our tests. The reason is that we select companies that indicate that they use Lean and have reported their performance. Our purpose, as indicated by the hypotheses, is not to test whether Lean is better or worse than other management philosophies. We contribute this paper to the understanding of how companies that have chosen to work with Lean can utilize it to enhance performance, and whether performance can be enhanced at all. This latter fact has another positive effect on the reliability of the survey. The respondents are companies working to some degree with Lean, and therefore they are knowledgeable about the Lean practices that they are asked about in the questionnaire. We consider this a strength of this study.

Of the 200 cases selected, the distribution of respondents was as follows: 17% CEOs, 29% department leaders, 43% production directors, and the remaining had other titles. Of the 200 companies, 40% is from the

“iron and metal” industry, 10% from electronics, 6.5% from construction, 6% from medico, and the remaining are from other industries. The “other” category consists almost exclusively of production companies. Therefore, the responding companies are mainly from what we may refer to as traditional production companies, except, maybe, for construction and medico. To ensure that construction and medico companies are not significantly different from the other companies, we performed a comparison test. For all questions, we compared the 25 medico and construction companies’ means with the 175 other companies in t-tests and found no significant differences. The non-parametric (Mann-Whitney U) test revealed the same pattern of no significant difference between the two groups. Furthermore, there was no significant difference in the means for the performance questions when we compared the different types of positions (CEO, department leader, production director, etc.) of the respondents.

### **3.2 Survey constructs and statistical technique**

Figure 1 and the related hypotheses call for a structural equation model (SEM) approach as the statistical technique. Multiple paths and mediations among constructs can be tested using structural equation modeling (Kline, 2005) instead of using multiple linear regression models to test each path before and after a mediator variable. Moreover, the structural equation model is able to include both observed manifest variables and latent variables in the same test run (Kline, 2005). Therefore, with the SEM approach, we get an overall assessment of the fitness of the data to the ex-ante model and an assessment of significance and direction for each path in the model. Hence, the SEM approach is attractive when addressing Lean as a system-wide model as in Figure 1. Additionally, Kline (2005) state 200 cases as an acceptable sample size to be used in structural equation modeling. Thus, the sample size is adequate for testing the survey answers in the structural equation modeling software.

We are not assuming equilibrium in our system-wide model. Hence, we have included a performance variable. A selection fit model is not used (Chenhall, 2007; Gerdin and Greve, 2003), as we assume that not all companies are in a complete fit. Actors within an organization cannot foresee all consequences of their actions, something that is required if the organization is to be in complete equilibrium (Luft and Shields, 2003). Performance is measured as a latent variable using four different measures as indicators. The first is a measure of cost per product unit reduction over the past fiscal year. The second measure is the reduction of worker time consumption per unit within the past fiscal year. The third measure is lead time reduction within the past fiscal year, and, finally, the fourth measure is reduction of materials per unit. Each of these measures is coherent with the measures that Lean companies are supposed to improve. They are measured on a 6-point reversed scale, where 6 represents the lowest (poorest) performance, i.e., deterioration of performance; 5 represents unchanged performance; 4 represents a reduction of 0-5%; 3 represents a reduction between 5 and 10%; 2 represents a reduction of 10-25%; and, finally, 1 represents a reduction of more than 25%.

The four measures were chosen in keeping with the fact that Fullerton and McWatters (2001) found a JIT performance effect on reduced scrap and rework. This will subsequently be reflected in our cost per unit, time consumption, and materials per unit measures. The effect of reduced inventory and queue time in production (Fullerton and McWatters, 2001) will be reflected in lead time reduction. Shah and Ward (2003)

use the manufacturing cost per unit and customer lead time in their study, where they also recognize an effect on scrap and rework.

As recommend by Kihn (2005), a factor analysis needs to be conducted in order to control potential conflicts that may arise when multiple performance measures are used. As expected a priori, a factor analysis of the four items of performance revealed only one factor (i.e., an eigenvalue greater than 1), and consequently no unexplained conflict between the performance measures. The Cronbach's alpha of the performance is .833, which is more than the 0.5-0.6 recommended by Nunnally (1978) for explorative research. Table 2 presents the factor analysis of the performance items. Moreover, Pearson correlations between the three measures revealed that they are significantly positively correlated.

< Insert Table 2 about here >

As mentioned above, the questionnaire administered in connection with the present study was constructed in order to collect information on the companies' use of 12 Lean practices. These Lean practices constitute 12 items in the questionnaire. The respondents were asked to note whether or not they employ a specific Lean practice, and, if not, whether or not they employ something similar. Thus, we received binary answers for each of the items.<sup>1</sup> The Lean practices asked about are shown above in Table 1, and the same Table also indicates how the 12 individual practices are grouped into constructs. A measure for each of the three constructs ("flow," "analytical continuous improvement," and "delegation of decision rights") is generated by adding up the number of practices a company uses within each construct/group. Hence, if a company uses two of the five flow practices, the score will be two for the flow variable of this company. Likewise, a score for the two other variables/constructs is calculated. The flow variable can be between 0 and 5, where 5 is the maximum number of practices related to this construct. Analytical continuous improvement empowerment can be between 0 and 4, and delegation of decision can add up to a maximum of 3 and a minimum of 0. The scores of the three constructs have to be analyzed as standardized (we therefore asses the standardized regressions coefficient in our test results), as they have different intervals, i.e., different maximum scores.

While most variables used in structural equation modeling are latent variables, it is also acceptable to use observed, manifest variables according to Kline (2005), which we have done with these three constructs of Lean practices. Single-item variables may suffice when the questions are unambiguous to the respondents (Sackett and Larson, 1990; Wanous *et al.*, 1997). This is likely in our study, as we only include those who indicate that they work with Lean to some degree. Therefore, it is likely that the respondents know the Lean practices they are asked about in the questionnaire.

In order to test whether our dataset is subject to non-response bias, a t-test comparing the first 10% of answers with the last 10% has been done. Armstrong and Overton (1977) recommend an approach like this,

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<sup>1</sup> The exception is "co-influence," which is measured on a 7-point scale. Nevertheless, we have converted this into a binary item.



as less ready respondents are more like non-respondents. The t-test on the performance reported by the earliest 10% of respondents compared to the last 10% respondents is non-significant. Hence, we find no sign of non-response bias.

Our last main construct concerns the behavior of middle management in regards to Lean. This construct consists of the three questions shown in Table 3. To assess these questions, a factor analysis of these is made. Here, the Cronbach's alpha is .909 and thus is higher than the recommended levels. Table 3 illustrates the factor analysis and related questions. Hence, it is empirically suitable to use the three questions as a reflection of a latent construct, "management," where "management" refers to the behavior of middle management.

*< Insert Table 3 about here >*

#### **4. Research results**

In this section, we present the statistical test results. First, we show the fitness of the structural equation model and then we assess the path coefficients to indicate either support or non-support for our hypotheses.

##### **4.1 Fitness of the model**

The model in Figure 1 is tested using SPSS AMOS 22.0 with the choice of maximum likelihood. This software is a recognized structural equation modeling tool. Before we can assess the path coefficients in the tested model in Figure 2, the fitness of the structural model must be evaluated. We use multiple fit indexes as recommended by Kline (2005). A single index may only reflect a particular aspect of model fit; hence, multiple indexes are needed to assess the overall model fit. Root Mean Square Error of Approximation (RMSEA) is a "badness of fit index" that should be as low as possible, and has a built-in correction for model complexity (Kline, 2005). We also present the incremental fit index (IFI) (Bollen, 1989), and the Tucker-Lewis Index (TLI) (Tucker and Lewis, 1973). The Comparative Fit Index (CFI) is widely used in SEM as an incremental fit index (Kline, 2005). The most basic fit measure is the model's chi-square, but this needs to be divided with the degrees of freedom to reduce the sensitivity of the index caused by sample size. This is labeled NC, Normed chi-square (Kline, 2005). As shown in Table 4, the goodness-of-fit statistics indicate acceptable fit to the data. Although the  $X^2$  is significant, the  $X^2$  ratio, NC, (divided by degrees of freedom) is less than two, indicating an acceptable fit (Bollen, 1989; Kline, 2005). The other fit indices (IFI, TLI, and CFI) exceed the acceptable level of .90, and the RMSEA does not exceed the acceptable fit measure of .08 (Browne and Cudeck, 1993). Moreover, the AIC measure is lower for the default model compared to the saturated model, indicating the parsimony of the model (Kline, 2005).

*< Insert Table 4 about here >*

## 4.2 Test results

Based on the fitness indexes in Table 4, we conclude that the analysis of the path coefficient and the content of the structural equation model in Figure 1 can continue, as the fitness overall is acceptable. Thus, test results of the model presented in Figure 1 are shown in Figure 2.

< Insert Figure 2 about here >

Figure 2 presents the output from running the SEM calculations. For each relation, beside each arrow, the path coefficient is given as standardized regression weights. For example, the relation between flow and continuous improvement empowerment is .45. Figure 2 further shows that this relation is highly significant, as it is marked with “\*\*\*” representing a  $p$ -value  $< .01$ . (The  $p$ -values are shown in superscript on each path and in brackets). This together supports hypothesis 1a.

Figure 2 also presents the squared multiple correlations coefficient for the variables that are dependent in a relation. These are presented in brackets just below the label of the variable. The squared multiple correlations coefficient can be interpreted as the explained variance of the dependent variable. Hence, by assessing both types of coefficients in Figure 2 and the significance level, we are able to assess our multiple hypotheses empirically.

Table 5 expands the test results in Figure 2 by showing the standard errors, the critical ratio, and an overview of the support for the hypotheses. Table 5 shows that many of the hypotheses are supported.

Hypotheses 1a, 1c, 2, 3a, 3b, 4a, and 4b are all supported in the structural equation model. However, hypothesis 4b is a borderline case, as the path coefficient has a  $p$ -value of .077. This weaker relation was already theorized in the hypothesis development section. The results indicate that higher use of delegation of decision rights and higher use of analytical continuous improvement practices positively affect performance.<sup>2</sup> Leading up to this is higher use of flow production practices, as these are positively associated with the two formerly mentioned variables, but flow production is not directly related to performance. Moreover, those firms having a middle management that is committed to Lean and is encouraging Lean will positively affect performance and analytical continuous improvement. However, the path directly from middle management to performance is not significant at a  $p$ -level of .01, but only at a  $p$ -level of .05. This could indicate that middle management's effect on performance is a somewhat mediated, indirect effect on performance by the other Lean practices, as described in the hypotheses development section.

< Insert Table 5 about here >

The mediating relation that analytical continuous improvement and delegation of decision rights has on flow production's effect on performance is already somewhat confirmed by confirmation of hypotheses 1a, 1b, 4a,

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<sup>2</sup> Notice that performance is scaled in reverse to analytical continuous improvement and delegation of decision rights, so a negative path coefficient means that they are positively associated.

and 4b. However, before confirming hypothesis 1c, we need to test the indirect effects on performance from flow production and we need to test the direct path between them. The direct path from flow production to performance is insignificant, with a standard coefficient of  $-.025$  and a  $p$ -value of  $.760$ . Both indicate that there is no direct performance effect from flow production. To further support hypothesis 1c, we tested the overall indirect effect on performance from flow production. This test supports hypothesis 1c, as the standardized path coefficient shows the correct direction with  $-.095$  and has a significant  $p$ -value of  $.007$  (two-tailed significance – PC). While testing the indirect effects, we also assessed the indirect effect from management on performance. This overall indirect effect is also significant, with a  $p$ -value of  $.011$  and a path coefficient of  $.035$ , correct direction. This supports the general approach that management’s role is somewhat mediated by the analytical continuous improvement variable, and, consequently, by delegations of decision rights, as they are related. Hence, this indicates that we should perceive Lean as a system-wide package.

Having assessed all the individual paths and the hypotheses thereof, we believe that it is not the individual paths that are most interesting, but the overall model and the perception of Lean as a system-wide model. Hence, we could label Lean a “package.” By supporting almost all of the hypotheses, and by showing the mediation, indirect effects, we believe that approaching Lean as a structural equation model is an interesting main test result.

## 5. Conclusions

This research provides some of the first empirical evidence that Lean practices function in a system-wide model to increase performance. Previously, Lean practices have been studied as separate elements or in an additive manner when the survey approach has been used. Hence, survey-based results have been mixed, as they did not capture the system-wide perspective that case studies and Lean experts believe to exist. We seek to close this gap by using a structural equation model approach with several variables in a system, based on a survey.

Testing our structural equation model representing Lean as a system-wide model shows that changing the operations of a business so it is more flow oriented does not itself affect performance. Indeed, flow production’s performance effects are mediated by continuous improvement founded upon analytical information support, and by delegation of decision rights with a group agenda. Moreover, middle management’s role is important, as this increases performance and is associated with more use of analytical continuous improvement. Analytical continuous improvement empowerment is also associated with more delegations of decision rights. Hence, it is possible for Lean organizations to affect performance positively. Implementing Lean as a piecemeal approach, however, may result in lowered performance, as our study indicates the need to perceive Lean as a system-wide model where individual Lean practices may not affect performance directly, but are mediated by other Lean practices. Thus, there are indirect effects on performance.

The documentation of the system-wide effects of Lean provided by this study, which a number of case studies have called for over the years, constitutes a main contribution of this study. Toyota himself describes Lean (Toyota Production System) as a system (Liker, 2004), and our empirics support this. By speculation, this may also be the reason why some companies complain about the lack of measurable performance effects stemming from Lean – this may be because they use scattered as opposed to system-wide practices and therefore do not experience sustainable performance effects.

## **6. Limitations and future research**

Future research, we believe, would benefit from following the same path as the one laid down in this study, i.e., following the recommendations of Lean case studies stating that piecemeal Lean implementation does not bring about improved performance. Our study, on the other hand, is limited by the binary nature of the possible answers to our questions on Lean practices. The implementation of a Likert-scale measurement would further the understanding of the performance effect to be gained through the use of a complete Lean package and a scattered implementation, respectively.

Our study is also limited by including neither the revenue effect of Lean practices nor the effects of these practices on the balance sheet. Incorporating return on assets, or the like, would also serve to improve the performance measure.

Furthermore, our findings are limited, as are all cross-sectional surveys, by not being able to demonstrate the existence of causal relations. Hence, we can only claim to have found evidence of an association between constructs. The directions of the associations are, however, supported by a priori theory.

## **7 Acknowledgements**

The authors would like to thank Danish Industry for providing us access to the data they have collected and for their collaboration.

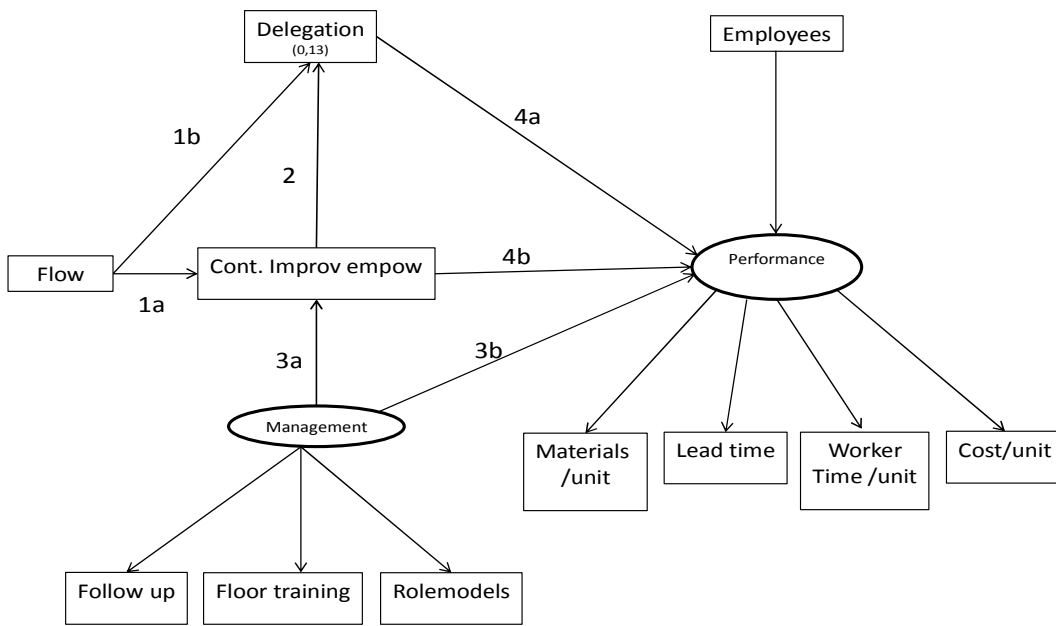


Figure 1: Hypotheses

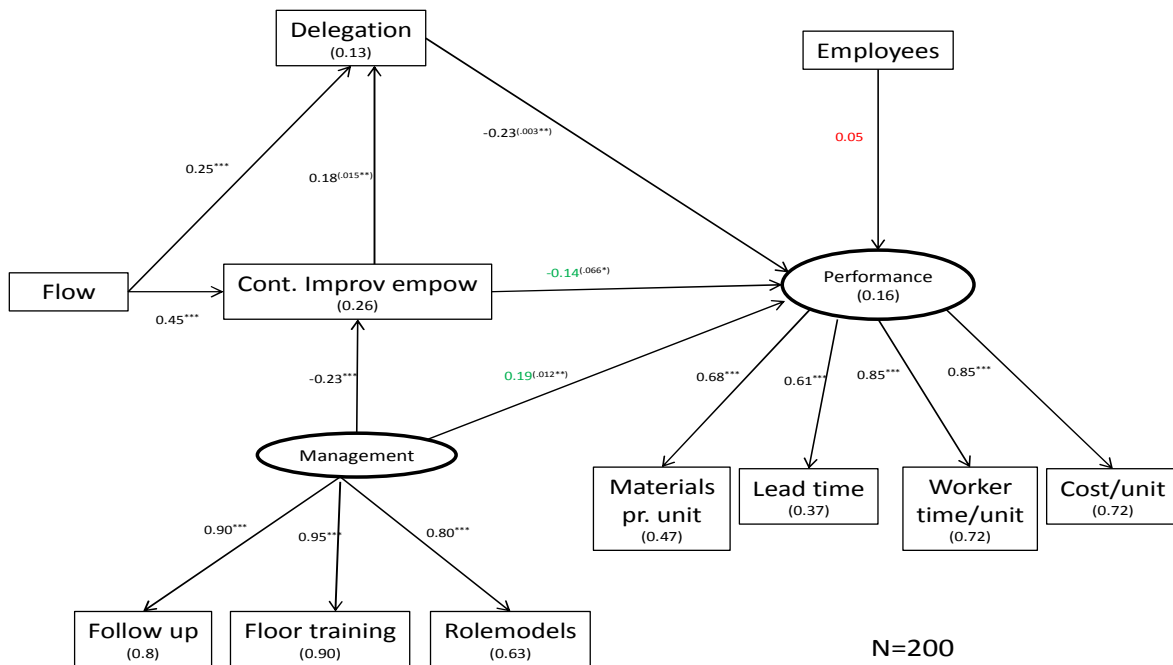


Figure 2: Test Results

<b>3 Main constructs</b>	<b>12 Practices</b>
<b>Flow production (physical operations)</b>	U-cell Production
	Kanban
	5 S
	SMED
	TPM
<b>Analytical continuous improvement (information empowerment)</b>	Kaizen
	Whiteboard Meetings
	Value Stream Mapping (VSM)
	Six Sigma
<b>Delegation of decisions rights (decision empowerment)</b>	Partially Self-controlled Teams
	Policy Deployment
	Co-influence on tasks

Table 1: The 12 Lean Practices

**Component Matrix**

	Component
	1
Cost per unit	.740
Time per unit	.745
Lead time	.567
Materials per unit	.643

Table 2. Factor Analysis - performance (n = 200)

**Component Matrix**

	Component
	1
The daily managers are good role models for their subordinates	.890
The daily managers are good at being on the shop floor and training their subordinates in Lean behavior	.944
The daily managers are good at following up on whether or not their subordinates are showing Lean behavior	.929

Table 3. Factor analysis – middle management behavior (n = 200)

Fit measure	Level
RMSEA	.069
IFI	.958
TLI	.942
CFI	.958
CMIN/DF (NC)	1.947
AIC (saturated)	132.000
AIC (Default)	129.865

Table 4. Fitness of SEM

Relation	Hypothesis	Supported	P-value	Standard error	C.R.	Standard coefficient
F → C.I.A	1a	Yes	***	.040	7.369	.452
F → D	1b	Yes	***	.039	3.320	.246
C.I.A → D	2	Yes	.015	.060	2.430	.180
M → C.I.A	3a	Yes	***	.052	-3.510	-.226
M → P	3b	Yes,	.012	.066	2.524	.190
D → P	4a	Yes	.003	.098	-2.970	-.223
C.I.A → P	4b	Yes, marginal	.066	.082	-1.839	-.141

Abbreviations used in Table 3: F = Flow Production; M = Lean Middle Management; C.I.A = Continuous improvement empowerment founded in analytics; D = Delegation of decision rights based on a group agenda; P = Performance

Table 5. Test results

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