

Lean principles in industrialized housing production: the need for a cultural change

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Abstract

The deep-rooted project culture in construction, e.g. including the one-of-a-kindness of the project, the production set up, the construction site and the temporary organization, is stated to be a hindrance when applying lean principles. However, the biggest challenge to achieving a long-term benefit of lean application in industrialized housing production (80 % of the work in a factory environment) is here argued to be to approach a lean culture. The aim of this paper is therefore to deepen the understanding of how to approach a lean culture in industrialized housing production.

A production questionnaire shows that industrialized housing production displays a project-based culture similar to that found in on-site construction with low motivation for, e.g., error-proofing and continuous improvement. Results from the questionnaire and a case study show that workers rather fix problems as they arise ahead of focusing on error-proofing and continuous improvement.

Lean Construction research has traditionally (up to latest years) focused on a top-down (top-management initiated project performance) tool approach to improve construction projects. However, theoretical and empirical proofs show that error-proofing and continuous improvement is statistically connected to worker motivation, and that workers follow standardized routines if they are visual and clear to workers. It is also shown that workers do not take own responsibility to obtain standardization in work and maintenance of equipment and tools. Therefore a simultaneous top-down/bottom-up (person focused) approach to achieve a lean culture in industrialized housing production is proposed. Generally, the study also points to more research to obtain a deeper understanding of lean culture and cultural change in construction.

Keywords: Lean principles, Lean culture, Industrialized housing

Introduction

Construction is a project-based industry where its unique characteristics are related to the one-of-a-kindness of the project, the production set up, the construction site and the temporary organization (Vrijhoef and Koskela 2005). These characteristics are part of the

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deep-rooted construction culture that has been put forward as a constraint when lean is applied in construction (Koskela 2003). It is however argued that in a lean application (aiming for improvement from a long-term view) a change is needed towards a lean culture (e.g. Liker 2004). A number of studies have focused upon the influence of the construction culture on lean application (e.g. Chan and Tse 2003). Not enough has been made to understand how to approach a lean culture in construction.

The construction sector is separated into different subdivisions, each with different characteristics. In this paper the aim is to understand a lean culture and how to approach a lean culture in one of these subdivisions - Swedish industrialized housing production where complete and ready-to-live houses are produced off-site in a factory. However, implementation strategies are not addressed.

Lean culture

Culture is a concept that generally refers to "the way things are done around here", and a culture approach is argued to increase the understanding of an organization both from a philosophic and practical view point (Pepper 1995). A more precise definition of culture is that by Schein (2004) who define culture in a development context, meaning that culture is:

"a pattern of shared basic assumptions that has been learnt whilst solving problems, that has worked well enough to be considered valid, and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems"

A lean culture relate to this definition because the concept of lean has developed through the years and is now considered to be valid for structuring and development of organizations. This argument is validated by the shown success of the Toyota production System and implementation attempts found in different industries, including construction (e.g. Diekmann et al. 2004). Liker (2004), among others, asserts that many manufacturing companies have implemented lean processes, techniques or tools, but without creating the underlying lean mind and culture. Bicheno (2004) give an explanation of what lean is and emphasize thinking peoples, workplaces and organizations that are more human. There is a difference between lean organizations and conventional organizations doing lean things (Veech 2004), why some companies fail in applying lean, and thus fails in approaching a lean culture. The difference lies in the way the company treats its workers. A conventional organization focuses on getting things from the employees, e.g. improved productivity, ideas and work, (Veech 2004), and very similarly Mann (2005) states that:

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

The key message is that it is not enough to just apply a lean principle or tool without a simultaneous strive for a lean culture. What is also needed is a balanced whole system view emphasizing improved performance through a focus on the persons delivering value to customers. We also find it clear that personal focus, involvement and motivation are imperative when applying lean principles and approaching a lean culture. In this respect, lean principles and practices can be seen as facilitators to both individual goals together with improved business performance.

Principles and practices representing a lean culture

Organizational culture is mostly influenced by practices used by the employees (Hofstede 2005). Hence, to understand a lean culture in this context, it is imperative to understand principles and practices of lean. The most frequently cited definition of lean principles found in the literature is that of Womack et al. (1996); *Specify value, Identify the value stream for each product, Make the product flow without interruptions, Let the customer pull value from the producer and Pursue perfection*. According to Womack et al. (1996), the five lean principles can be applied in any business. This argument is plausible because these principles are obviously specified on a philosophic level, and are thus possible to vary and apply within different business contexts. However, these five principles define lean without specifically emphasizing individuals and their creativity. Instead, the goal of satisfying the end customer simultaneously promoting an effective flow is clearly pronounced, i.e., the focus is on production performance. Although employee practices are found in Womack et al. (1996), we notice a lack of pronounced person focus in the five lean principles. This might be misleading because individuals are an essential part of a lean culture according to Liker (2004), Veech (2004) and Mann (2005); hence, cultural aspects should be found in every attempt to approach lean in a business.

“The house of lean production” is a recognizable symbol and a visual model of lean that includes both the goal of the production performance and the person focused approach of involvement. Taiichi Ohno and Eiji Toyoda at the Toyota Motor Company first created the visual model. However, today different versions of the model including different principles and practices are found (e.g. in Liker 2004 and Dennis 2002). Hence, a review of manufacturing literature was performed to find the most commonly cited lean principles and practices when evaluating and assessing application of lean. In the review 13 articles were identified (e.g. Shah and Ward 2003, Soriano-Meier and Forrester 2002) and four lean production principles and 17 corresponding practices crystallized. These were fitted to our view of the house of lean production, which is presented in Figure 1.

The lean practices that in this way were found in literature only refer to the in-house production and thus leave aside customer and supplier relationships, i.e., considering only industrialized housing *factory production*. The rationale for this demarcation follows the “traditional lean implementation” strategy (Ballard and Kim 2007) to start in the in-house (factory) production system and thereafter extend to value creating activities among suppliers and customers.

Lean approach in construction

Most lean approaches in construction are concentrated in the Lean Construction (LC) concept. The academic debate in LC is to challenge the traditional understanding of projects based on theories of economics, and adopt project management based on theories of production (Koskela and Ballard 2006, Ballard and Howell 2004). Picchi and Granja (2004) have employed an inductive approach analyzing work performed in the LC field. By summarizing examples of lean tools used on job sites, Picchi and Granja identified three lean implementation scenarios:

- Scenario 1: Fragmented tools application
- Scenario 2: Integrated job site application

- Scenario 3: Lean enterprise application

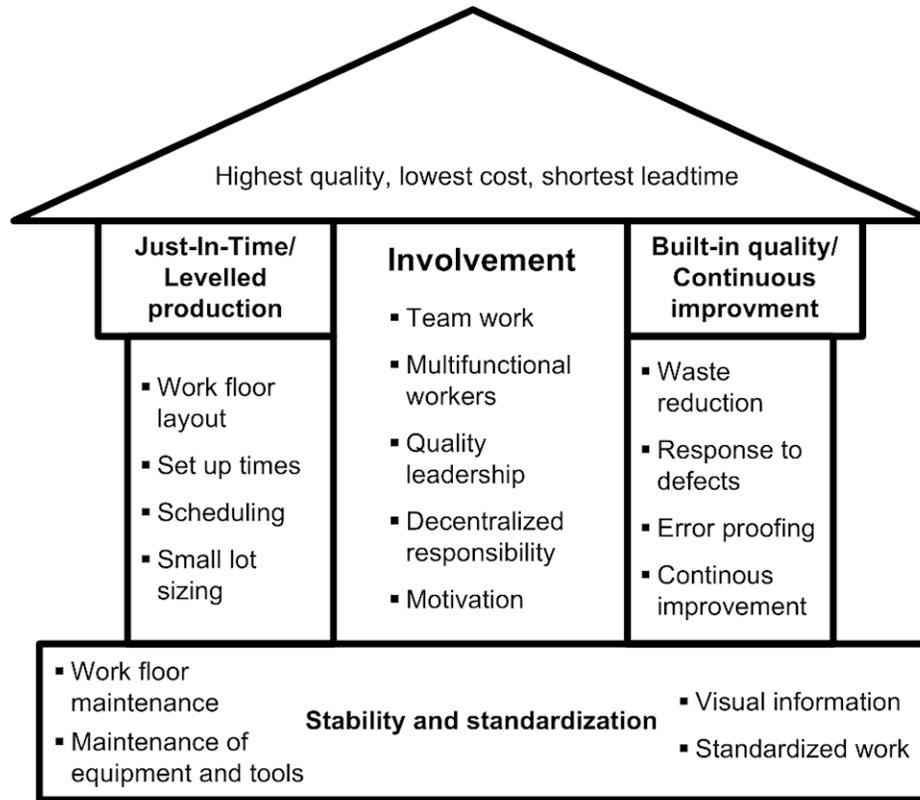


Figure 1: The house of lean production in the context of the literature review, representing a lean culture in industrialized factory production

The construction industry is found in the first scenario, where the focus is on applying specific tools to specific projects (Picchi and Granja 2004). Lean is dealt with in the logic of projects where the realization has been fragmented. This means lean approaches have mainly focused on project performance improvement through tools and techniques in terms of project settings, such as flow, value, buffers, etc (Pavez and Alarcon 2007). Hence, the path followed within LC can best be described by a top-down (project performance goals set by top management) approach. This means an approach that is based on a whole system view (which indeed is a lean approach), but where the focus on individuals and peoples are subordinated. However, we argue that the basis of a lean approach is met by achieving a lean culture. The reviewed literature tells us that long-term improvements of a lean approach are best achieved via a simultaneously top-down/bottom-up approach. A bottom-up (person focused) approach implies workers using specific working routines thereby forming the culture, and where lean tools can improve how the traditional things are done. A simultaneous top-down strive implies top management setting the goals of project performance.

Is there at lack of a bottom-up approach in construction? Pavez and Alarcon (2007) and Green (2000) identify a theoretical lack of human, organizational and cultural issues in LC research. Contrarily, Alves and Tsao (2007) question the argumentation of a cultural lack. Their summary of major research areas in LC from 2000 to 2006, based on “keywords”,

indicates that “culture and human aspects” are among the top ten categories found in LC research. Thus, two different viewpoints exist. There is either a lack of human and cultural issues in LC as stated by Pavez and Alarcon (2007), or there actually is one of the top categories in LC as stated by Alves and Tsao (2007). To clarify this discrepancy, we reviewed papers presented within the International Group of Lean Construction (IGLC) annual conferences from 1996 to 2007. From this review, a clear trend was discerned with an increase in discussions about cultural issues and human aspects on lean application in construction during recent years (from 13% for 1996 to 2001 up to 29% for 2002 to 2007).

Swedish industrialized housing

Swedish industrialized housing production (off-site prefabrication) was empirically evaluated regarding how to approach a lean culture, based on the present production culture. Industrialized housing is a division of the Swedish construction sector. Industrialized housing production generally combines different levels of on-site and off-site activities. Three types can be distinguished; off-site prefabrication of materials and parts, prefabrication of components and subassemblies, and prefabrication to where 80% of the work is completed off-site in a factory environment (Gibb, 2001; Gann, 1996; Höök and Stehn, 2005). The third type of industrialized housing construction is treated in this paper. The empirical study is based on the complete number of Swedish companies using industrialized Timber Volume Element (TVE) housing production, where in a factory, a TVE is a closed three-dimensional structure built up with components and subassemblies to floor, roof and wall elements and completed with electrical installations, flooring, cabinets, wardrobes, finishing etc. The volumes are transported to the construction site and assembled by the company’s personnel into a complete structure, Figure 2.

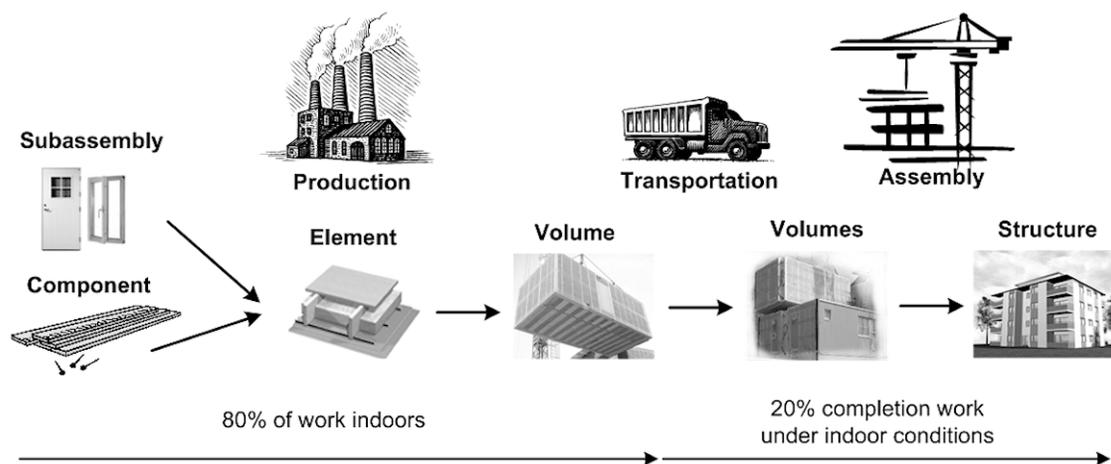


Figure 2: Industrialized TVE housing production

Research method and empirical results

To provide an understanding of the present production culture as a basis to understand how to approach a lean culture, the practical working methods of industrialized housing production were evaluated from a bottom-up perspective. This perspective starts from a

detailed understanding of the fundamental practices and processes of the production system. An overview of the research design is outlined in Figure 3.

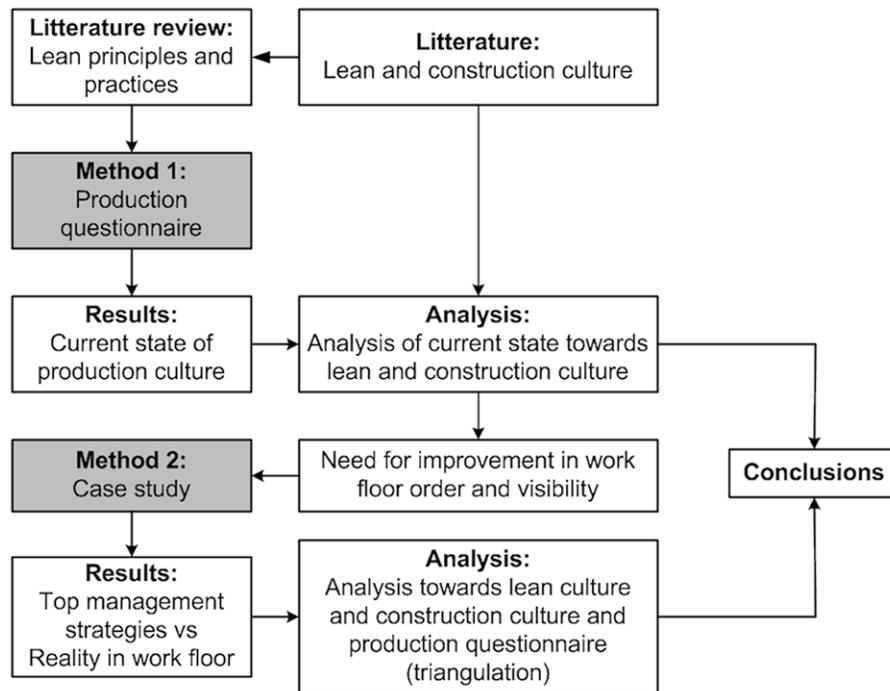


Figure 3: research design

The first empirical evaluation was achieved through the production questionnaire based on the 17 practices found in literature and presented in Table 1. The questionnaire was designed around pairs of statements corresponding to the 17 lean production practices. One of the statements corresponded to a lean culture, as defined by the literature review, while the other statement presented an opposite view. A five-point Likert scale was used in the questionnaire where a 5 implies a lean type behaviour and a 1 the opposite.

Table 1: Practices facilitating a lean culture from a bottom-up view

1. Work floor layout	7. Error proofing	13. Motivation
2. Set up times	8. Continuous improvement	14. Work floor maintenance
3. Scheduling	9. Team work	15. Visual information
4. Small lot sizing	10. Multifunctional workers	16. Maintenance of equipment and tools
5. Waste reduction	11. Quality leadership	17. Standardized work
6. Response to defects	12. Decentralized responsibility	

The studied companies have not any history of using lean or any lean implementation intention at present, why the questionnaire was tested on a small group of employees to assure that the questions were comprehensible. The questionnaire was then distributed among all the production workers in the TVE prefabrication companies (in-company employees and sub-contractors as electricians and painters that work in the production plants). The response rate was almost 100% due to the researchers' personal presence and delivery of the questionnaire, and totalled 291 completed questionnaires. The data was screened for missing values and outliers and entered for statistical analysis. On a 0.05 significance level it was shown that the employees' at all companies had apprehended the questions in the same manner. The average score from the questionnaire was calculated for each of the 17 practices, Figure 4.

The 17 practices were also entered for Principal Component Analysis (PCA). The purpose of the PCA was to compare the current behaviour and culture in the production of industrialized housing to the lean culture as defined by the structure of the lean principles and practices found in literature, Figure 1. Varimax rotation was used to extract orthogonal components and 4 components and the corresponding PCA-based loadings obtained are shown in Table 2. The components A-D are highly interrelated and assumed to represent dimensions within the data. The naming/labelling of the components is dependent on their corresponding practices.

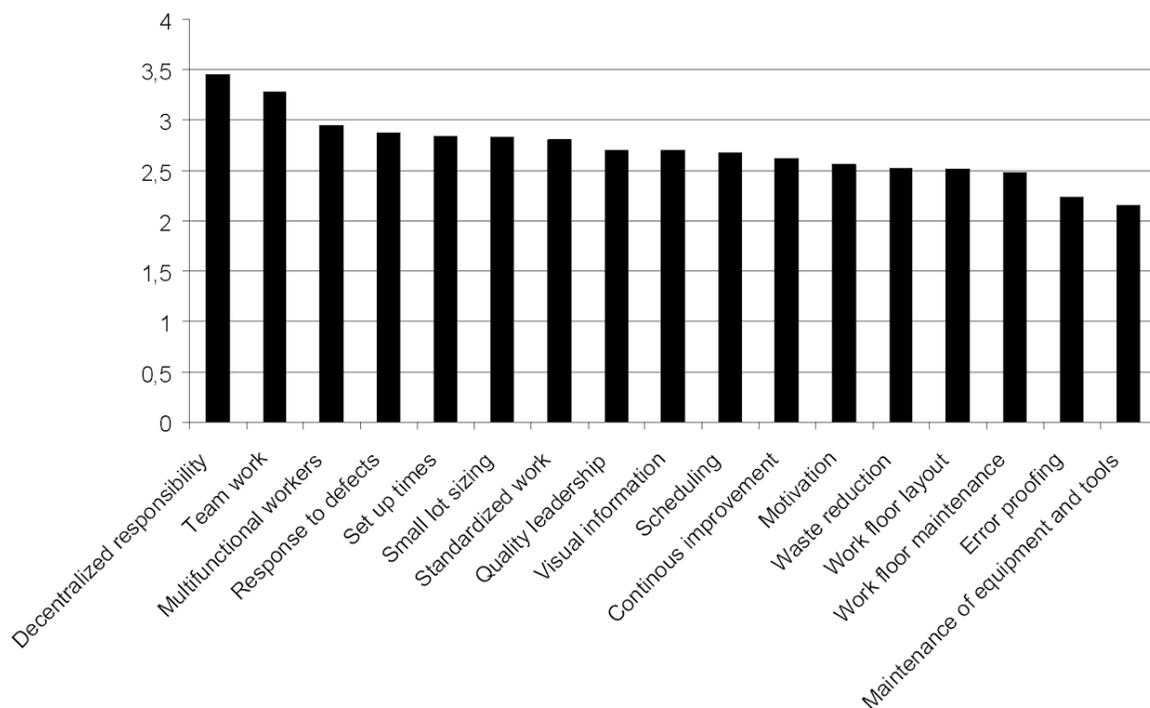


Figure 4: Average score for the 17 practices

The results from the questionnaire, Figure 4, show that the practices with the lowest average score are correlated to the extracted component "Work floor order and visibility" in Table 2. Work floor order and visibility are areas important to achieve a lean culture (Ho 1999). Work floor order and visibility improves thinking processes and helps to achieve change in attitudes of people to quality by making the work place a better place for

workers which in turn create thinking peoples (Hirano 1990). Therefore, the practices of this component were further evaluated to deepen the understanding of the present production culture, and to validate the questionnaire regarding the area that seem to be most important to improve if the aim is to reach a lean culture.

A case study was undertaken at one of the four studied TVE companies. The case study involved three study visits at the production facility and was mainly based on observations of the production, and included low structured personal interviews with production employees (ten interviews), production management (two interviews) and top management (two interviews). The three practices related to component D in Table 2 were guiding the interviewing. Data gathered were answers from the interviews e.g. regarding the work floor maintenance; what is the top management strategy and what is the reality on the work floor (including observations and production worker interviews). At the study visits personal observations and photos corresponding to, or contradicting, the interview answers were gathered. The results from the case study, related to the results found in the production questionnaire, are provided in Table 3. The case study was analysed within case using clustering of data and thereafter related to literature. To obtain triangulation results were also compared to the results from the production questionnaire.

Table 2: PCA with naming of extracted components

Naming of extracted components	Practices	Extracted components			
		A	B	C	D
A: Just-in-time/ Leveled production	Scheduling	0,75			
	Small lot sizing	0,62			
	Set up times	0,62			
B: Motivation for Built-in- Quality and Continuous improvement	Error proofing		0,65		
	Motivation		0,65		
	Continuous improvement		0,64		
	Multifunctional workers		0,63		
	Response to defects		0,6		
	Team work		0,52		
	Waste reduction		0,5		
C: Responsibility for standardization	Quality leadership			0,45	
	Decentralized responsibility			-0,68	
	Standardized work			0,65	
D: Work floor order and visibility	Maintenance of equipment and tools			0,41	
	Work floor maintenance				0,73
	Work floor layout				0,7
	Visual information				0,65

Table 3: Result from the case study

There are established factory layouts for how and where material and equipment should be stored, but these are seldom in accordance with the reality on the work floor.



There are continuous cleaning routines, where cleaning once a week has been decided, but the responsibility areas for cleaning are not settled and the practice is that everyone cleans after themselves.

Lack of settled responsibility for standardized cleaning results in material waste and rubbish that may remain lying beside a work station.



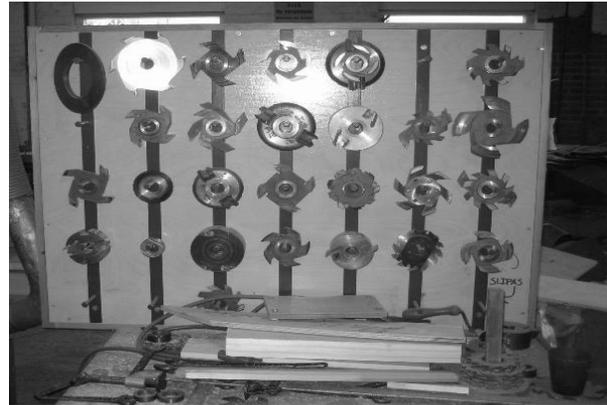
A frequent argument from workers when cleaning is discussed: *“Should we clean or produce?”*

Material without any natural or settled repository is placed on the first empty place found near to a work station.



Generally, there are no markings or visual signs for where material or equipment should be placed and stored.

There are some examples of shelves and places for material that are marked, and where material and equipment are always found on the right and decided place.



Analysis and discussion

The analysis is based on the questionnaire (PCA and Figure 4) and the case study (Table 3). The rating scores from the questionnaire illustrate that only parts of a lean culture are found in the daily working routines concerning work floor order and visibility. From Figure 4 it is evident that the practices *work floor maintenance* and *work floor layout* received the lowest ratings. These results were validated by the case study interviews and observations. The workplace has settled layouts but still production workers place material wherever they find it easiest at that moment. Certain cleaning routines are claimed to be in effect, but because of insufficient strategies and unspoken responsibility areas from top management, piles of material waste are often found beside work stations. Generally, the visibility in the studied factory seems low, but there are some examples of visual markings for material and equipment, see Table 3.

The question *“Should we clean or produce?”* from workers also implies an almost reluctant culture towards cleaning and order. Still, workers only mirror what seems to be an unspoken upper management strategy for a high production pace ahead of work floor order and visibility. The culture or worker behaviour in industrialized housing is therefore evidentially connected to the arguments by Mann (2005), Veech (2004) and Eton and Carpenter (2000), saying that a focus on results will result in problems related to lack of interest from workers. Additional evidence of this is found in the PCA in Table 2, which shows that built-in-quality (component B) is on a 0.05 significance level related to whether the workers are motivated and organized towards error proofing and continuous improvement. Increasing built-in-quality in industrialized housing thus requires higher

worker motivation, as connected (albeit a weak connection) to quality leadership, e.g. meaning that leaders often should be seen and working in the production plant. The low rating of error proofing (2.3 on a 5 point scale) in the questionnaire adds to this analysis of workers not taking responsibility and managers who do not support experience feedback and problem analysis. The culture in a project or a business is often a reflection of the leadership and organizational structure as argued by Zuo and Zillante (2005). Taking these observations to an application situation, Hirota and Formoso (2001) emphasize that learning from lean production principles and practices is strongly influenced by cultural views and beliefs. Signals from upper management are important for motivation commitment, and that leadership is relevant to ensure success (Alarcon and Diethelm 2001).

The practice of decentralization statistically and negatively loads on component C in Table 2, i.e., an increase in the standardization of work and equipment maintenance is achieved when the workers' responsibility is decreased. Hence, this observation implies that standardization can best be obtained if work methods, at least in the beginning, are set up by management. This is an empirical proof for the need of a top-down approach to bring about a strategy or a culture. Another empirical evidence points to the importance of clear top-management strategies. The production questionnaire and the case study show need for improved work floor order, equipment maintenance and visibility. Hence, an implementation initiative of the 5s tool (lean tool for improved order and visibility (Hirano 1996)) was initiated at one of the TVE production facilities. 5s practices were implemented (middle management was involved). However, top-management had not taken a strategy to implement lean or the 5s tool, why the initiative eventually fizzled out.

It is however not enough just to focus the cultural change from top-management. Case studies presented in Mann (2005) shows that visual controls and information are important enablers for disciplined focus and adherence to a lean culture. This is validated in this study by the PCA forming the significant component D showing a connection between visual information and work floor order. Also the case study results show the connection between visual information and work floor order. Results from the questionnaire further show that workers give the highest rates to practices that they can influence by themselves (responsibility, team work, and response to defects). This implies that routines and work practices that workers can influence, also influence workers, and thus has the ability to influence the culture from a bottom-up level. This relates to Hofstede (2005) meaning that organizational culture is influenced by work practices. The empirical result of industrialized housing production thus calls for a top-down approach (clear lean strategy from upper management towards production performance) and a bottom-up approach together (tools or methods such as visual information that both motivate employees and attain the performance goal).

In general, a similar construction culture is found in industrialized housing (despite manufacturing likeness) as in construction. Indeed industrialized housing shows the highest rates in the production questionnaire for the practices decentralized responsibility, teamwork, multifunctional teams and response to defects. This illustrates a culture (also found in traditional on-site construction projects) where employees working in flexible teams take responsibility for their own tasks, where problems are solved, but where the experience diffusion is limited. The results herein support the trend in LC to study the culture and propose methods to improve performance to also incorporate the development of tools with a simultaneous purpose of changing culture and improving performance.

However, the generalization between industrialized housing production and construction in general is not clear. Industrialized housing started on a larger scale 15 years ago. What is evident is that they only moved the housing production indoors - into a factory, and still they have a production culture with large similarities to a traditional construction culture.

Conclusions

To achieve long-term benefits of a lean approach in industrialized housing production, it is herein implied that primarily there is a need for a cultural change towards a lean culture. A focus on individuals is an essential part of achieving a lean culture. Empirical evidence from this study and reviewed literature first shows the necessity of clear top management strategies, and secondly the importance of changed work practices as facilitators of a change in culture. Thus it is argued that to move toward a lean culture, from a long-term perspective in industrialized housing production, there is a need for a simultaneous top-down and bottom-up approach diffused to workers. The bottom-up approach specifically means that tools and techniques motivate workers towards a lean behaviour and mind. Hence, the purposed approach has a system view because the lean tools show the direction for worker towards a lean culture. A lean culture can not merely be obtained by management that proposes a strategy. Instead a culture is achieved when peoples find a strategy (or principles, practices and tools) to be working.

Another conclusion is the need to obtain a deeper understanding of the organizational culture when approaching (and eventually implementing) lean is discussed. The empirical evidence shows that it is not enough just moving into a factory environment to approach a lean culture. Industrialized housing and traditional on-site construction show both similarities and differences. However, we argue (still to be proved) that the whole construction sector is founded on a general construction culture independent of specific characteristic in product, market and production settings. Thus the understanding of how to approach a lean culture in construction in general is necessary. There is an ongoing and expanding understanding of this need in LC related research. We argue that the person focus is an important part of a lean culture, and it is the authors belief that this can and should, along with the "peculiarities of construction" (one-of-a-kindness, on-site construction and the temporary organization), be used as an intrinsic constraint when adopting and applying lean in construction.

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