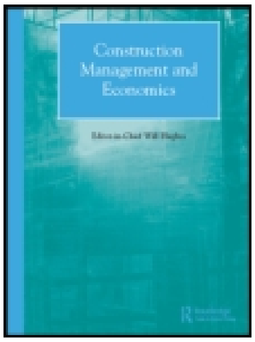


Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

# Applicability of lean principles and practices in industrialized housing production

Matilda Höök & Lars Stehn

*Construction Management and Economics* (October 2008) **26**, 1091–1100

# Applicability of lean principles and practices in industrialized housing production

MATILDA HÖÖK* and LARS STEHN

*Department of Civil and Environmental Engineering, Luleå University of Technology, Luleå, 971 87 Sweden*

Received 27 November 2007; accepted 18 August 2008

The applicability of lean principles and practices to industrialized housing in Sweden are examined, taking the production culture into consideration. The factory production of industrialized housing shows apparent similarities to manufacturing, but areas related to fully integrated lean production practices, such as error proofing and standardized work floor and equipment maintenance, are scarce. Hence, applicability of lean principles and practices to industrialized housing production is clearly influenced by a production culture that has similarities to a traditional construction culture. Setting up industrialized housing production thus requires careful implementation of lean principles if workers from traditional building are moved into factories, and managers still adhere to the prevailing site-based production mentality. However, the influence of the traditional construction project culture is not solely a constraint; flexible teams that take their own responsibility are also important in a lean culture. Hence, retaining parts of the existing construction mentality, context and way of working is also central when discussing lean applicability in industrialized housing.

*Keywords:* Lean production, lean construction, industrialized housing, culture.

## Introduction

Arguments found in a broad literature review indicate that construction, in general, displays a delay in developing towards higher productivity, quality and decreased costs compared to manufacturing (Winch, 1998). Having empirically verified the benefits of lean production in manufacturing through case studies of several automobile plants and other industries, Womack *et al.* (1990) hypothesize that lean principles can be applied to any industry, including craft production sectors. Applications of lean principles to construction have also been found (e.g. in Howell, 1999; Koskela, 2000). Based on a literature review and six case studies Diekmann *et al.* (2004) argue that successfully applied lean principles in construction can improve the cost structure, value attitudes and delivery times. However, evidential results from a field case study indicate that applicability of lean principles requires a facilitating organizational culture and mentality (Motwani, 2003).

*Author for correspondence. E-mail: matilda.hook@ltu.se

The New United Motor Manufacturing, Inc. (NUMMI), the joint venture between general Motors and Toyota, where lean principles and practices are successfully implemented in an automobile plant with initial poor industrial conditions (Waurzyniak, 2005), shows that it is possible to change organizational culture towards a lean culture. However, in construction the settings of the traditional construction project culture seem to influence the applicability of lean. The discussion of possibilities and limitations on the applicability of lean to construction often takes its standpoint from a cultural perspective. The unique characteristics of the construction industry, 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) are part of the deep-rooted construction project culture that has been put forward as a constraint when lean is applied in construction. A number of studies have focused upon the influence of the construction industry culture on lean application in traditional construction projects (e.g. Chan and Tse, 2003). Studies with an attempt to measure the organizational culture of a company are few (e.g. Diekman *et al.* 2004; Abuduh and Roza, 2006;

*Construction Management and Economics*
ISSN 0144-6193 print/ISSN 1466-433X online © 2008 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/01446190802422179

Salem *et al.*, 2006) and deal with onsite, project-orientated construction. Not enough studies have been done to assess the culture and understand the influence of culture on the applicability of lean principles to industrialized housing. Hence, the aim of this research is to assess the applicability of lean production principles and practices, the production culture and its influence on the applicability, in Swedish industrialized housing production.

## Lean principles in construction

### Construction—a project culture

Project culture in a construction context has been defined as: 'the shared values, basic assumptions and beliefs that the participants involved in a project hold that determine the way they process the project and the relationship with each other in the project environment' (Zuo and Zillante, 2005). A strong project culture remains unchanged even if people leave or join the project, and if anything does change, the behaviour of the people is to change to match the culture. The characteristics of construction imply a project culture that is argued to complicate the adoption of new approaches such as lean principles (Cox, 1996; Low and Mok, 1999). From an organizational point of view, it is argued that the hindrances to applying lean principles are in part explained by the dynamic nature of construction with its constantly changing one-off relationships and in part due to the fact that construction contractors only control a small portion of the construction value stream (Diekman *et al.*, 2004).

In general, the constructive culture in construction projects has often resulted in methods that actually meet customer demands, e.g. concerning flexibility of the product, though this culture brings about a limitation of knowledge and experience diffusion from one project to another (Dubois and Gadde, 2002). The 'problem-solving' mentality in construction projects does not allow current problems to be evaluated because it is an intrinsic part of the culture (Winch, 1998) and actors seem reluctant to change the traditional allocation of responsibilities and the traditional way of working (Bröchner *et al.*, 2002; Bulhões *et al.*, 2006). In construction, overcoming the mindset and 'common sense' that exist appears to be a barrier towards change (Ward and McElwee, 2007). It is important to recognize that implementing lean is argued to act as a catalyst to promote a cultural change (Kumaraswamy *et al.*, 2002), but in construction the project culture seems unaffected by a lean implementation.

The two main obstacles (both caused by the project culture) in applying lean principles to construction seem to be:

- different types of variability (the range of possible outcomes of a given situation) causing uncertainties and instability in production;
- the mentality of actors, e.g. reluctance to change.

### Lean construction—a project approach

Much of the lean application in construction is concentrated in the lean construction (LC) concept. The production theory of LC is founded on the work of Lauri Koskela (e.g. Koskela, 2000), who introduced the transformation-flow-value (TFV) that is influenced by and associated with diverse economic and management theories, such as Walras's production function, the scientific management approach of Taylor, the quality movement originated by Shewhart, and the flow concept derived from lean production and the Toyota production system (TPS) (Winch, 2006). Even though the original lean approach developed in the TPS is also a collection of diverse management techniques, the LC concept is not a 'direct' attempt at applying lean production principles and practices to construction. Instead, new tools are developed, e.g. the 'last planner system' of production (Ballard and Howell, 1998; Ballard, 2000), and others are discussed and applied in construction, e.g. line-of-balance (LOB) scheduling (Kenley, 2005), and project management approaches such as value stream mapping (Arbulu *et al.*, 2003). These tools and approaches mainly cope with variability in an attempt to stabilize the construction workflow within the project environment.

An ongoing academic debate within the LC community is to challenge the traditional understanding of projects based on theories of economics, and adopt project management based on theories of production (Ballard and Howell, 2004; Koskela and Ballard, 2006). However, Pavez and Alarcón (2007) and Picchi and Granja (2004) argue that lean is implemented in the logic of projects, showing that most implementations within LC have been fragmented, and have mainly focused on project performance improvement through the application of new tools and techniques in terms of project settings, such as flow, value, buffers, etc.

### Industrialized housing—a process approach

The definition of industrialized housing followed in this paper is: 'Production in a closed factory environment where only assembly is performed at the construction site, with one evident process owner and a clear product goal of repetition in housing design and production'. The empirical study is based on the complete number of Swedish companies using industrialized timber volume element (TVE) housing production where about 80% of the work is completed off site (Höök and Stehn, 2005). The production company embraces the whole construction process, from design to factory production of a complete house (see Figure 1).

The house is produced as 'ready-to-live' volumes (with integrated finishing, cabinets, electrical installations, etc.) that are transported to the construction site and assembled there into the complete house. This is clearly a process-orientated factory production, and companies employing this approach have also displayed an increased control of the total construction value chain, a reduction of the workflow variability due to repetition in operations, and a stable and permanent work organization (Höök, 2005).

It is argued that housing construction offers the closest analogy to lean production and matches that of auto production (Barlow, 1999; Winch, 2003; Womack *et al.*, 1990). However, there are limits to which manufacturing techniques derived from the car industry can be applied to housing construction. Two notable features separate the industrialized housing construction of today from manufacturing (also valid for onsite construction). The first is connected to customer relations. A customer requirement often found in housing projects is a demand for almost unlimited flexibility, a demand that often changes over time and between projects (Höök, 2006). This complicates the transfer of lean principles and practices to housing construction because the lean philosophy is about identifying a specific value and promoting flow based on a certain and known number of components. Adding this 'constraint' to the many complex parts making up a house renders it difficult for industrialized housing companies to obtain leanness, unless the product and the working methods are heavily standardized. Fluctuations in customer demand, during and between projects, also add to this by unbalancing and destabilizing of the product pull. The second feature concerns supplier relations. Large manufacturers as well as Japanese house builders that have adopted lean have supplier systems based on a rational framework for determining costs, price and profits where both parties can benefit from working in a cooperative relationship (Gann, 1996). Firms such as Toyota and Toyota homes are large enough to influence the strategies of suppliers, though this is often not the case with smaller industrialized housing companies.

## Lean process culture as an assessment framework

The developed lean approach in the logic of projects in LC is not a functional theoretical ground for cultural assessment of industrialized housing production where production is based on a repetitive process approach. Hence, lean production (LP) is chosen as a characterization of a process culture. The definition of culture followed in this paper is: 'a pattern of shared basic assumptions that has been learnt whilst solving problems, that has worked well enough to be considered valid' (Schein, 2004). This implies that the culture of LP corresponds to assumptions and practices and production methods that are developed and considered to be valid for a process approach. Therefore, principles and practices supporting the LP culture are used as a bottom-up assessment framework for production culture and lean applicability in industrialized housing production. In creating a lean production system, and a true lean culture, the relationship between customer and supplier relations and the actual production system is crucial. Here, only factory production of industrialized housing is considered because it follows the 'traditional' lean implementation strategy over time (Ballard and Kim, 2007) to start in the in-house (factory) production system and thereafter extend to value-creating in the whole company and finally in the whole value chain, thus creating the lean enterprise (see Figure 2).

In recent years, numerous articles focusing on the assessment and applicability of lean principles and practices in the manufacturing industry have been published. A review of manufacturing literature was performed to find the most commonly cited lean principles and practices that are used when applicability of lean principles is evaluated and assessed. A summary of the literature review is shown in Table 1.

From the review, four lean production principles and 17 corresponding practices became obvious, and these were related to principles and practices in 'The house of lean production' (e.g. Dennis, 2002; Liker, 2004) (one of the most recognizable symbols of lean production). The four lean principles and the 17 practices

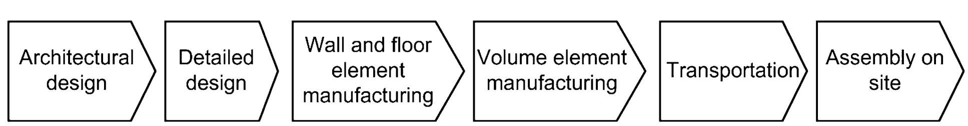


**Figure 1** Production process of industrialized TVE housing from design to complete building

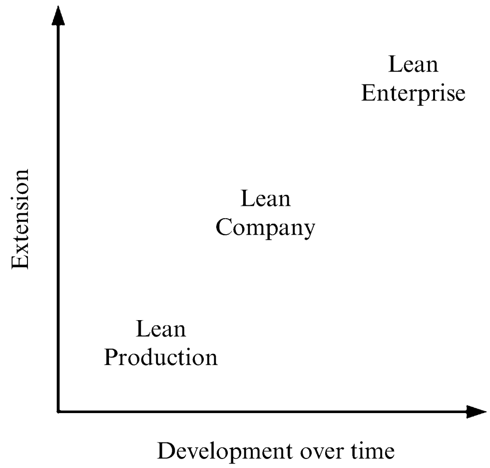


**Figure 2** Traditional lean implementation strategy (inspired by Womack and Jones, 1996)

form the assessment framework used in this research, presented in Table 2. The assessment framework is not claimed to be all-inclusive, but it does represent the most frequently cited principles and practices supporting a lean process culture found in literature. Therefore the framework represents a current snapshot of how the LP theory is used and adopted in practical research-based assessments.

All practices related to production flow were combined to the *Just-in-time/Levelled production* principle. The meaning of this principle is that each process produces only what is needed, when it is needed in the amount needed, by the next process in a continuous flow. The principle of *Built-in quality/Continuous improvement* includes practices related to preventing defects to proceed in the process, where the visualization of problems and error proofing are essential ingredients. Practices related to motivation and empowerments were combined to form the principle of *Involvement.* The foundation in LP lies in creating *Stability and standardization*, a principle formed by the practices representing operational and human stability and reliability, i.e. operating as needed, with predictable outcomes.

## Assessment of culture in industrialized housing production

Following the definition of culture (related to practices and work routines), empirical data were collected to

**Table 1** Summary of literature review

| Practices / Author | Work floor layout | Set-up times | Scheduling | Small lot sizing | Waste reduction | Response to defects | Error proofing | Continuous improvement | Teamwork | Multifunctional workers | Quality leadership | Decentralized responsibility | Motivation | Work floor maintenance | Visual information | Maintenance of equipment and tools | Standardized work |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boyer (1996) | | | | | | | | | X | | X | | X | | | | |
| Doolen and Hacker (2005) | | X | X | | | | | | | | X | | | | | | |
| Flynn *et al.* (1999) | | | X | X | | X | | X | X | | | X | X | | | X | X |
| Goodson (2002) | X | X | X | X | | X | X | X | X | | | | X | X | X | X | X |
| Karlsson and Åhlström (1996) | X | | X | X | X | X | | X | X | X | | X | | | X | | |
| Kobayashi (1995) | | X | X | X | X | X | X | X | X | | X | | | X | | X | X |
| Koufteros *et al.* (1998) | X | | | X | | X | X | X | | | | X | | X | | X | |
| Nightingale and Mize (2003) | X | X | | X | | | | X | X | | | X | | | | | X |
| Panizolo (1998) | | X | | | | | X | | X | X | | | X | | | | |
| Schonberger (1982) | | X | | X | X | X | | X | | | | X | X | X | | X | |
| Shah and Ward (2003) | | X | | X | | | | X | | X | | | | X | | X | |
| Soriano-Meier and Forrester (2002) | | X | | X | X | X | | X | X | X | | X | | | | | |
| Taj (2005) | X | X | | | | X | X | | X | | | | X | X | | X | |
| Tapping *et al.* (2002) | | | X | | | X | X | X | | | | X | X | | X | | X |

**Table 2** Assessment framework based on literature review

| Lean production principles | Lean production practices |
|---|---|
| Just-in-time/Levelled production | Work floor/layout |
| | Set-up times |
| | Scheduling |
| | Small lot sizing |
| Built-in quality/ Continuous improvement | Waste reduction |
| | Response to defects |
| | Error proofing |
| | Continuous improvement |
| Involvement | Teamwork |
| | Multifunctional workers |
| | Quality leadership |
| | Decentralized responsibility |
| | Motivation |
| Stability and standardization | Work floor maintenance |
| | Visual information |
| | Maintenance of equipment and tools |
| | Standardized work |

understand the practical work methods of TVE housing production. Characteristics for the four studied TVE housing companies are shown in Table 3, where the total number of employees and turnover for all production facilities of the specific companies are included.

Data were gathered using a questionnaire, which was based on the assessment framework in Table 2, and designed around pairs of statements corresponding to the 17 practices. One statement describes the ideal state according to a lean culture while the other statement supports a corresponding, but opposite state. A five-point Likert scale was used to measure the continuum of the agreement related to the opposing statements. The population of interest in the empirical study was Swedish industrialized TVE production facilities with housing production. This means that only one production facility from each company was included in the population of interest. Respondents were workers at the four TVE housing companies comprising in-company employees, and subcontractors as electricians and painters that work in the production plants. The studied companies had no previous experience with lean or any lean implementation attempts at present, and the employees were not familiar with lean or manufacturing terms. Hence, the questionnaire was first tested on a small group of employees to ensure that the questions were comprehensible. The questionnaire was personally distributed and supervised by the researcher and the number of completed questionnaires was 291, with 87% response rate. Validation of the results was obtained through comparison to other studies of TVE housing production, i.e. the questionnaire was validated through

**Table 3** Company characteristics

| Company | Production facilities | Turnover (M Euro) | Number of employees |
|---|---|---|---|
| A | 2 | 38 | 220 |
| B | 1 | 42 | 100 |
| C | 4 | 42 | 300 |
| D | 1 | 7 | 33 |

triangulation. Data were screened for missing values and outliers and the requirements for normality and linearity were tested and confirmed. Statistically, the studied companies show small differences, which is why it is possible to generalize the results to industrialized TVE housing in Sweden.

Two methods were used to statistically analyse the questionnaire: measuring of mean values and a principal component analysis (PCA). The mean values were used because they tell something about the work methods and thus the production culture. A mean value of 3 for a practice means that there are parts of both lean and non-lean behaviour, and a value of 2 means that there are more parts related to the non-lean behaviour than related to the ideal lean state. The interpretation using the five-point Likert scale without more precise descriptions of the specific states (1 to 5) means that it is possible to compare the evaluated practices. The average score from the questionnaire was calculated for each of the 17 practices (see Table 4).

The PCA was used because of its ability to analyse a set of variables and identify dimensions within the data that are latent. In this case the PCA was used to evaluate whether the grouping of principles and

**Table 4** Mean score for the 17 lean production practices

| Lean production practices | Mean |
|---|---|
| Decentralized responsibility | 3.45 |
| Teamwork | 3.28 |
| Multifunctional workers | 2.95 |
| Response to defects | 2.87 |
| Set-up times | 2.84 |
| Small lot sizing | 2.83 |
| Standardized work | 2.80 |
| Quality leadership | 2.70 |
| Visual information | 2.70 |
| Scheduling | 2.68 |
| Continuous improvement | 2.62 |
| Motivation | 2.56 |
| Waste | 2.52 |
| Work floor layout | 2.51 |
| Work floor maintenance | 2.48 |
| Error proofing | 2.23 |
| Maintenance of equipment and tools | 2.15 |

practices found in the literature (assessment framework in Table 2) is valid also in industrialized housing production. The 17 practices were entered for PCA with the used Varimax rotation to extract orthogonal components; four components and the corresponding PCA-based loadings obtained are shown in Table 5. The component loading represents the correlation between the original practice and its component. For a sample of over 200 respondents, a 0.05 significance level is obtained for loadings exceeding $\pm 0.40$ (Hair *et al.*, 2006). Loadings exceeding $\pm 0.50$ are generally considered necessary for practical significance. The loadings of quality leadership and maintenance of equipment and tools are thus treated as low-correlating to the related extracted components.

Component A is almost similar to the principle of Just-in-time/Continuous improvement in Table 2, despite the practice of the work floor layout that loads on Component D. Component A is therefore still interpreted simply as 'Just-in-time/Levelled production'. Practices with the highest correlation to Component B have special emphasis on the motivation practice which is why the component is interpreted as 'Motivation for BIQ and Continuous improvement'. Component C correlates to practices such as decentralized responsibility and standardized work and is logically named 'Responsibility for standardization'. Finally, Component D correlates highly to practices related to work layout, maintenance and visibility, and is therefore named 'Work floor order and visibility'.

## Applicability of lean principles and practices

The empirical result shows four new 'principles' (components A to D in Table 5) that are based on the respondents' comprehension of the work routines. The difference between the new components B, C and D and the grouping in Table 2 is important. For component B, the built-in quality is apparently statistically related to whether the workers are motivated and organized towards error proofing and continuous improvement. A likely explanation is that the project culture sets the norm for the behaviour, highlighting the problem that workers do not take responsibility and managers do not support experience feedback and problem analysis. Increasing built-in quality thus requires higher worker motivation, which is connected (albeit a weak connection) to quality leadership, meaning for example that leaders are often present or working in the production plant. Similar arguments, i.e. that the culture in a project or a business is often a reflection of leadership is found in Zuo and Zillante (2005).

The practice of decentralization negatively loads on Component C, indicating that any change or development in standardized work and maintenance of equipment and tools requires upper management and strategy changes because today the workers do not feel that they have the responsibility from the upper management to take measures when defects are detected. This observation implies that standardization can best be obtained if work methods are set up by management. Construction workers are probably used

**Table 5** Naming of components derived in the principal component analysis

| Naming of extracted components | Practices | Extracted components | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| A: Just-in-time/Levelled 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 | | |
| | Moviation | | 0.65 | | |
| | Continuous improvement | | 0.64 | | |
| | Multifunctional workers | | 0.63 | | |
| | Response to defects | | 0.60 | | |
| | Teamwork | | 0.52 | | |
| | Waste reduction | | 0.50 | | |
| | Quality leadership | | 0.45 | | |
| C: Responsibility for standardization | Decentralized responsibility | | | −0.68 | |
| | Standardized work | | | 0.65 | |
| | Maintenance of equipment and tools | | | 0.41 | |
| D: Work floor order and visibility | Work floor maintenance | | | | 0.73 |
| | Work floor layout | | | | 0.70 |
| | Visual information | | | | 0.65 |

to ad hoc solutions where standardization is scarce and worker responsibility has to come from upper management. The need for a top-down management when lean principles are applied in industrialized housing is apparent. Other observations of a reluctance to change mentality (Bröchner *et al.*, 2002) and the necessity for a continuous improvement culture (Motwani, 2003) also point in this direction.

The empirical evidence in Component D shows that the practice of work floor layout does not seem to be connected to the lean flow JIT-component, as in manufacturing-related frameworks. Hence, production workers do not connect factory design and layout to flow. Component D further shows a connection between visual information (such as visual markings of where different equipment should be placed) and the work floor order and maintenance. This result relates to findings from Mann (2005), whose case studies have shown that visual controls and information are important enablers for disciplined focus and adherence to a lean culture.

## Production culture in industrialized housing

The mean values of the assessed lean practices are generally low in the studied industrialized housing companies. Table 4 shows mean scores for the practices between 2.15 and 3.45 (on the five-point scale), indicating a production culture where only elements of a lean process culture are found. Table 6 shows mean values for the practices with the lowest values together with the statements related to the specific practices.

Maintenance of equipment and tools has the lowest rating, relating to a traditional construction project culture where standardized maintenance of equipment and tools is not very common, and where tools are used until they are broken. If no spare tools are available the task waits until a new tool is ordered and delivered, an aspect considered the 'normal feature of the business' as stated by Vrijhoef and Koskela (2000). The second lowest rating in Table 4 concerns the practice of error proofing. Error proofing on a production worker level means that problems are analysed and solved to not arise again, followed by notifying others. This low rating is related to and explained by the construction project culture where knowledge and experience diffusion from one project to another is limited (Dubois and Gadde, 2002). The low rating of work floor maintenance and layout practices adds to the discussion of construction mentality and project culture.

The workers answering the questionnaire only reflect the culture they belong to and it is apparent that project culture still very much influences factory production. The industrial TVE housing production culture is characterized by (shows the highest mean values for) decentralized responsibility, high response to defects, teamwork and multifunctional workers, implying employees who work in flexible teams that take responsibility for their own tasks. We also see this as a clear indicator of a pronounced problem-solving mentality and culture. A culture also found in onsite construction projects, where building workers work in teams (Vrijhoef and Koskela, 2005) that are responsible for understanding design drawings, performed tasks, etc. Together with the low rating of the practice of error proofing, the high response to defects emphasizes a problem-solving culture, where problems are solved, but not further analysed and spread to others.

The results found are clearly connected to earlier studies of Swedish industrialized TVE housing (e.g. Höök and Stehn, 2005), where problem areas such as the lack of factory layouts were indicated. A PCA does not show evidence of causality per se, and mean values only indicate a relationship, but the shown similarity in results to other studies validates the merit of the results in this study.

**Table 6** Mean values and description of statements for practices

| Opposite to ideal state | Practice and mean value | Ideal state in a lean process culture |
|---|---|---|
| Equipment is repaired when it gets broken and waste of time is common | Maintenance of equipment and tools Mean value: 2.15 | Equipment is maintained and cleaned according to plans and routines |
| Action is taken when problems are detected but it is common that problems arise again | Error proofing Mean value: 2.23 | Primary causes are always examined |
| The workplace is messy and unorganized | Work floor maintenance Mean value: 2.48 | Clean and ordered work floor where tools and material have fixed places and are found in the right place |
| Material is found all over the workplace. Unnecessary movements cause waste of time and resources | Work floor layout Mean value: 2.51 | All materials have obvious places in the workplace and few places are unused |

## Conclusions

It is argued that lean principles can be applied to any business though its application to construction has met with constraints, such as different types of variability and the mentality of construction actors, as compared to the manufacturing industry. Elements of a lean process culture, such as control of the total construction value chain, a stable and permanent work organization, repetition in operations and flexible workers who take their own responsibility, can be found in industrialized housing production. However, it is shown that the production culture in Swedish industrialized housing production still relies on, and is characterized by, a traditional construction project culture. The influence of the construction project culture implies:

- low worker motivation and awareness of built-in quality, continuous improvement and flow;
- problems that appear are solved but are seldom thoroughly analysed, and with restricted experience diffusion;
- ad hoc solutions and a low responsibility for maintenance of equipment, tools, work floor and work floor layout.

It is apparent that the applicability of lean principles and practices to industrialized housing is influenced by, and meets the same type of difficulties, as onsite construction, i.e. the hard-to-change project culture and mentality of workers and managers. The case of the NUMMI automobile plant shows that it is possible for a poor organizational culture to change towards a lean culture (Waurzyniak, 2005). However, industrialized housing has moved into an industrial environment, but still the strong onsite-related project culture remains. This emphasizes the importance of, and also the difficulty in, change of culture towards a lean culture in construction.

Development and change towards a lean production culture in Swedish industrialized housing requires:

- increased worker motivation and responsibility for flow, built-in quality and continuous improvement, through a leadership that guides and motivates workers;
- standardization of work, work floor layout and maintenance of equipment and work floor, to obtain flow in production, measurable quality and improvements, and increased worker motivation.

It is shown that these requirements are clearly connected to management that is conceived from the upper organization. However, workers in industrialized housing have to be able to try new (lean) working methods because they will re-evaluate assumptions if specific working methods work well enough to be considered valid. Hence, a change in culture, that facilitates a lean application in industrialized housing, requires understanding from upper organization of the importance of clear strategies, and the change power of workers.

There are also elements originating in the construction project culture, such as flexible teams that take their own responsibility, that are also important in a lean process culture. Awareness and exploitation of this already natural part of the production culture is central when discussing the applicability of lean principles in industrialized housing.

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