

THE TOYOTA PRODUCT DEVELOPMENT SYSTEM APPLIED TO A DESIGN MANAGEMENT WORKSHOP MODEL

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ABSTRACT

Within a lean framework the goal is to enhance productivity by maximizing client value and minimizing waste known as muda. In the construction industry focus has mainly been on minimizing waste within the construction site production process. However, research has shown that a great amount of the waste experienced during site assembly can be traced back to the early design phase. In addition minimizing waste does not guarantee overall project success if client values are not fully understood. Indeed it is possible to effectively produce a product that the client does not value. This paper reports the early findings of a research project which aims to develop a workshop method for lean design management in construction through a deeper understanding of the Toyota product development system (TPDS) and value theory in general. Results from a case-study will be presented and a theoretical comparison of the workshop model with lean principles will lead to proposals for further development of the workshop approach to design management.

KEY WORDS

design management, lean product development, value management, workshop method, product value, design reviews

INTRODUCTION

In spite of its potential Lean Product Development (LPD) or 'Lean Design' has received little attention in the construction industry compared to

research and application of Lean in site production. In addition focus seems to be skewed towards flow management and waste reduction as opposed to managing and enhancing client value (Jørgensen, 2006). This paper attempts to address the latter. Initially a

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terminological basis should however be established. In spite of its central importance the conception of 'customer value' is only vaguely defined in lean management literature. The customer (as well as the delivery team) in construction comprises multiple stakeholders (funders, client organization representatives, end-user etc.) with different values, experiences and time-horizons of interest, which causes a different management challenge compared to what is 'normal' in the manufacturing industry in which lean originates. In addition complexity is increased by the fact that the involvement of individuals change during the project (Blyth and Worthington, 2001) and the development process, in which change is embedded, creates various gaps between client expectations (aspirations, plans etc) and reality. It is the client's perception of these gaps that forms the basis of client satisfaction (Boyd and Chinyio, 2006). Thus, recognizing the complexity of the construction client, the paper will focus on the concept of 'value' and LPD as a theoretical basis for developing the workshop method described in (Emmitt et al, 2004, 2005), which is introduced briefly. Findings of a case-study are then reported, which leads to a discussion of the workshop method and proposals for its development into a lean design management approach.

Recognizing the correlation of different management techniques the workshop model can be viewed as a value management approach (see Kelly et al, 2007). However, the aim of the research project is to develop the method through adoption of LPD principles to form a holistic approach that not only captures client values and

reviews design solutions, but forms a framework for design management in construction projects. Acknowledging that design management has various meanings (see London et al, 2005) it should be noted that by design management the authors of this paper mean managing and integrating the design process between multiple stakeholders (companies) on a construction project. For the time being the research is deliberately limited to exclude the strategic organizational management within the design firm, although this of course interfaces with management at a project level. Attention is focused on the early conceptual phase, given that this is where the scene is set for everything that follows. Finally the authors recognize the potential of addressing the psychological aspects of design management (e.g. proposed by Sebastian, 2004) which will be broached in the discussion of 'value' although focus, within this paper, will be on LPD.

VALUE

Even though most people have a feeling of what is meant by the term "value", it seems to be difficult to formulate a common definition. In construction one of the first known attempts to define value was made by the Roman architect Marcus Vitruvius Pollio (died about 25 BC) who wrote that all architecture should possess strength, utility and beauty¹. It is often overlooked that Vitruvius also mentions the importance of considering "the nature of the place" or suitability to surroundings in his

¹ Or firmness, commodity and delight depending on translation of the ten books of Vitruvius (book 1, chapter 3)

sixth book, chapter 2 (Vitruvius). This highlights the range of the value concepts in construction. However recent attempts to try to define value are more mathematical, according to Kelly the most common definition is (Kelly, 2007):

$$\text{Value} = \frac{\text{Function}}{\text{Cost}}$$

However, value can also be looked at from a more philosophical point of view which to a great extent complicates the conception of value. On the basis of literature review (see Thyssen et al, 2008), the following characteristics have been identified that should be taken into consideration when addressing the concept of value:

- Value will in most cases be a subjective judgment depending on human interest (Perry, 1914; Thomson et al, 2003). This entails that some (if not all) value(s) changes over time (Perry, 1914)
- The term 'value' (a judgment) can be distinguished from the term 'values' – the individuals core beliefs, morals and ideals (Thomson et al, 2003)
- An item can in some cases be objectively measured as more or less valuable compared with another item (Thomson et al, 2003). However the objective valuation (often) depends on context e.g. what the environment can supply, group consent etc. (Smith, 1948; Thomson et al, 2003)
- A valuation can be said to be more durable if many people agree on it and it is based on 'right' assumptions/information (Perry, 1914)

- Value can be instrumental (Smith, 1948)
- Value can be found not only in connection with a physical object, but also in activity, love, goodness, friendship, knowledge etc. (Bradley, 2006). Specifically value can be experienced within a process towards a goal (Rice, 1943).
- Value is also distinct from quality which can be viewed as the level of objective fulfillment of prescribed requirements (Rice,1943; Thomson et al, 2003)

LEAN PRODUCT DEVELOPMENT

Lean Product Development (LPD) or Lean Design is a relatively new area of research compared to the massive coverage of lean production (Baines et al, 2006, Haque and James-Moore, 2004). LPD is in some cases thought of as lean manufacturing principles applied to product development (e.g. Haque and James-Moore, 2004), however the product development process is inherently different from the manufacturing process and should be treated as such. Focus is on achieving customer value and therefore 'lean' sometimes means adding more resources via 'frontloading' which may seem as a wasteful approach in traditional lean thinking (Haque and James-Moore, 2000). The TPDS can be viewed as the source of LPD and is therefore the starting point of the present developing theory of application in construction. A literature review of TPDS has led to the following essentials:

- Toyota conducts extensive customer analysis prior to each

development program, where engineers try to experience the needs of the targeted customer group e.g. moves in with them (Morgan and Liker, 2006).

- A strong leader, the chief engineer (CE), who has the sponsorship of executive management and is highly revered within the organization, is responsible for the development program from start to finish and acts as a system integrator (Womack et al 1990, Morgan and Liker, 2006, Baines et al, 2006).
- The CE and his staff, who represent the customer, write a concept paper describing the vision that is to be regarded as the 'law' of the program. Work is aligned by decomposing the vision in specific objectives for each functional team. The objectives can to some extent be negotiated which adds to the commitment (Morgan and Liker, 2006).
- Cross functional cooperation is achieved through the forming of Module Development Teams (MDTs). Focus is on face-to-face team integration not coordination (Karlsson and Åhlström, 1996). Meetings are kept effective through extensive preparation and the use of simple and visual communication e.g. A3 paper format posters (Morgan and Liker, 2006)
- A lot of resources are spent in the early phase (frontloading) exploring several design alternatives simultaneously (set

base engineering) (Morgan and Liker, 2006, Baines et al, 2006).

- Product and production process are co-developed (concurrent engineering) and system compatibility is given high priority (Womack et al, 1990; Morgan and Liker, 2006). A customer first mentality settles conflicts between different functions e.g. between stylist and engineer (Morgan and Liker, 2006).
- Information is 'pulled' just in time (Haque and James-Moore, 2004)
- Engineers performs a hands on approach and integrates relevant suppliers in the development process (Morgan and Liker, 2006)
- Process, engineering skills and components are standardized as a means for productivity and continuous improvement (Haque and James-Moore, 2004, Morgan and Liker, 2006)
- A learning culture, which honours and actively 'produces' highly skilled engineers, with a constant strive for improvements (Morgan and Liker, 2006).

LEAN DESIGN IN CONSTRUCTION

Reviewing the relatively sparse literature on Lean Construction Design there seems to be a skewed focus towards flow management and waste reduction as opposed to managing and enhancing client value (Jørgensen, 2006). It is notable that the same tendency is found in manufacturing (Haque and James-Moore, 2004, p. 29). Accordingly, techniques such as the Design Structure Matrix (DSM)

and the Last Planner system of Production Control for coordination and scheduling of design tasks have been promoted in several publications (e.g. Koskela et al 1997, Hammond et al, 2000), but a holistic approach with equal emphasis on the value creation aspect of construction design seems to remain absent. However, there appears to be an increasing interest in the ‘value creation perspective’ and some propositions of applying QFD (e.g. Koskela et al 2002) and target costing (Ballard, 2006) can be viewed as developments in this respect, together with the work of the authors (e.g. Emmitt et al, 2004, 2005).

THE WORKSHOP MODEL

The intention is to explore client values on the basis of the client brief at the outset of the project stage (model process Blyth and Worthington, 2001, p. 204) and incorporate these into the conceptual (sketch) design through a series of creative workshops. However, acknowledging the importance of trust and

communication, a partnering workshop is held prior to the value management workshops. The workshops are outlined in figure 1 (obtained from Emmitt et al, 2005)

At the partnering workshop (workshop 0) all relevant client stakeholders meet with representatives of the design team (architects and engineers) together with representatives of the construction team. No matter what procurement route or contractual arrangement used, the aim is to keep the design and delivery team together throughout the entire project and via the partnering workshop establish the basis for trust and effective communication. In order to operationalise the concept of value, distinction is made between product and process values. The partnering workshop is concerned with the latter, understood as the values that the entire project team holds regarding cooperation and work ethics. Through discussion and consensus building, a partnering charter is made that reflects the agreed ‘process values’.

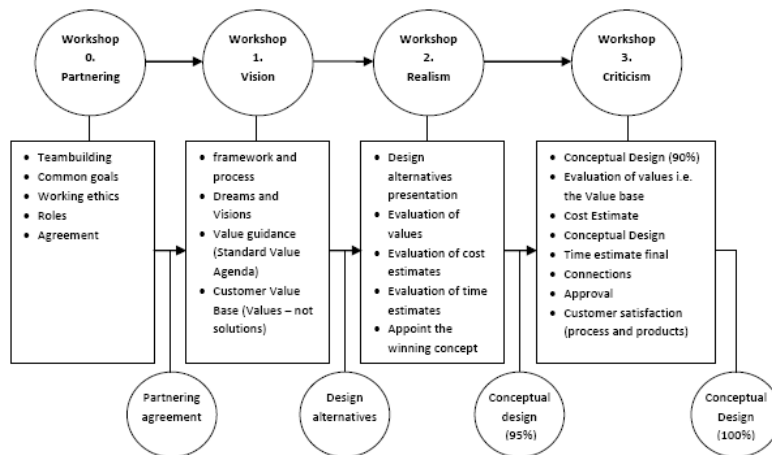


Figure 1: The creative workshop model (Emmitt et al, 2005)

Workshop 1 is concerned with client ‘product values’ understood as

underlying values that determine client needs and expectations regarding the end-product. The aim is to make the

product values explicit and reveal potentially hidden values to address potential conflict up front. Also, the objective is to facilitate a common understanding of the project objectives (the vision) and thereby reduce downstream uncertainty in design and construction. The client organisation is not asked simply what kind of building it desires, because the client may have a limited point of reference in order to envisage a construction facility. Investigation of client values is done via a standard value agenda, comprising the main headings of: Beauty, Utility, Durability, Harmony with surroundings, Environmental issues, and Buildability (inspired by Vitruvius). A value tree is established from the main headings to help prioritize values.

At workshop 2 at least three design alternatives are presented to the client and construction team and the options are evaluated against the product values. Also time and cost restraints are introduced as well as any authority restraints. A decision matrix, in which the designs are ranked according to conformance to the value system, can be applied for guiding the decision making process. A winning proposal is then selected for further articulation.

The winning proposal is evaluated at workshop 3 called the criticism workshop which aims to further optimize the design. In addition the process is evaluated against the partnering charter as a starting point for the continuous cooperation in the subsequent stages of detailed design and construction.

THE CASE STUDY

The case-study project consists of two buildings of 3 and 5 floors with 42 apartments which cover 3600 m². The

client is a non-profit organization that owns 13,000 dwellings in the Copenhagen area. The 'client' comprises a board of residents but would be termed an experienced client in a Danish context. The dwellings are constructed with financial support from the municipality which therefore has a right of disposal of some of the flats. Within this project, these flats are mainly for elderly people who require care and families with a disabled child.

The application of the workshop model was set up through earlier cooperation between a consultancy company, who has developed the workshop model, the client and the architectural firm, and via funding from the Danish Ministry of Social Welfare. However, the participants did not have prior experience with the workshop model except for the process-facilitator. The first workshop (workshop 0) was conducted in the spring 2005 and the process continued into the autumn of 2005 where the last workshop was held, after which the contractor withdrew because of financial concerns. In the autumn of 2007 a new contractor was found and it was decided to restart the project as well as the workshop process, to integrate the contractor and evaluate the design, which, at this stage, was very well developed. This second round of applying the workshop model was initiated at the same time as the present research project had started and even though it was biased by the 'first round' it was found to be a good case for initial investigation of the workshop method. The results of the case-study, reported below, were obtained through non-participant observation.

CASE STUDY OBSERVATIONS

The workshops were held with an average of 13 participants (some specialists did not attend all of the workshops). At the end of workshop 3 an evaluation of the process was conducted by means of anonymous questionnaires. The participants were asked to rank the process against each

of the process values on a scale of 1-10, where 10 was to be considered the best (see Table 1 below). The overall average was 9 with a variance of 0.85 which indicates great satisfaction among the participants (9 respondents). The lowest individual score given by any of the participants was 7.

Table 1: 'process values' evaluation

Partnering charter (process values)	<i>average score 1-10</i>
We will be trustworthy	9,33
We will respect each other – both personally and professionally	9,11
We will be loyal to the decisions made	9,13
We will be ready to make compromises where our initial personal interest needs to give way for other interests	9,00
We want good communication and we will make sure to inform all (relevant) participants on progress in matters	8,67
We will be constructive regarding changes and solutions	9,11
We will keep options open as long as possible (last responsible moment)	9,13
We will balance expectations and goals and use our resources rationally (no need to ask for CAD drawings if a sketch will provide the sufficient information)	8,67
We will work according to coordinated schedules and be respectful to other professionals operation	8,50
We will keep our agreements	9,13

The biggest benefit of going through the workshop process again was new insight into the needs of the older end-users, who were less mobile and needed more care than originally anticipated. End-user representatives provided this information, which initiated a very creative process to generate more space in the bathrooms and bedrooms and supplement the ventilation system with air injection to improve indoor climate, all which were successfully accomplished within budget. Some other changes were suggested by the client, which were found not to be feasible, however additional assessments were made to ensure adaptability, so that these changes could be made in the future. In this process all participants contributed, however it was critical that the contractor's representatives

were experienced enough to make cost estimates on the spot (which was not the case in the first application of the workshop model and it hampered the decision making process). The client expressed great satisfaction with this change and the contractor found it motivating to know that the facility to a greater extent would satisfy the needs of the end-users.

Within this process, it was a supporting factor that the client representative was enthusiastic about the workshops and possessed the authority of an experienced professional who were able to make decisive decisions – this had a contagious effect on the rest of the team. However, some critical observations were also made:

- Several comments were made regarding the workshop model being very time-consuming (each session lasted about 4-5 hours)
- After workshop 3 the architect and contractor were so confident and eager to get on with the detailed design and construction that they did not consider a fourth workshop, about integrated design and construction scheduling, to be necessary; so they carried on without it.
- The architects expressed some annoyance about making the changes
- The value tree was not rigorously used by the architects when presenting the design solutions. It seemed more like ad-on explanations for some of the design choices being made, rather than an integral part of the process.
- Participants were much better at discussing solutions than value and values.

DISCUSSION AND ANALYSIS OF THE FINDINGS

The case-study shows that even though the workshop model had already been conducted a second round of discussing client needs gave way for new insights and an improvement of 'product value'. This highlights the importance of taking time to understand client needs (frontloading) and corresponds with the notion that needs (value) changes over time. Even though it is not possible to generalize the findings, the case-study also indicated that the workshop model can

facilitate good cooperation through a discussion of 'process values'. Furthermore, the case-study highlighted the importance of the experience of the participants as well as their mandate to make decisions on the spot. This calls for a thorough participant analysis. However the professionals' time is precious and great effort should be directed towards limiting the duration of the workshops. Greater acceptance of design changes that arose during the workshops, may be facilitated by some renegotiation of client values with the delivery team to establish greater commitment and thus 'durability' of values. The extent of frontloading in relation to the type of project should also be considered. The haste of the architect and contractor to progress may be reasonable if indeed they had a clear sight of what was to be done and when to do it. Finally the case-study shows that discussing value and values is a difficult thing to do and a more rigorous use of QFD might help to translate the client values into a (technical) language understandable to building professionals. Attention to communication barriers within the design process, which is dependent on psychological and cultural aspects, is also highly relevant, but the topic is too intricate to be addressed in this paper.

The findings correspond with the lean methodology in the following respect: (1) the importance of a "Large-project-leader" (in this case the Client) to be the change agent, (2) the ability of the participants to explore alternatives and make decisions, (3) the importance of means for efficiency in meetings – there is a great risk of lengthy meetings within the teamwork approach, (4) the importance of policy deployment as

regards to translating client value into design criteria and facilitating a commitment to accommodate these, (5) the value of early involvement of production orientated participants and finally (6) the value of frontloading the

process. In table 2 some of the critical lean design principles are compared with the workshop model to show similarity and suggestions for development inspired by the TPDS.

Table 2: Lean principles versus the workshop model

<i>Lean principle</i>	<i>The workshop model</i>	<i>Suggestions for development</i>
'Large project leader' as a change agent	The workshop model does not provide any means to accommodate this principle	Appoint an independent 'system integrator' who will serve the interests of the client and has the sponsorship to do it.
Understand client value and create a value hierarchy	Use of a value tree	Rigorous use of QFD. Some level of negotiation of product objectives to create commitment among design and delivery team.
Frontload the process	Imbedded in the concept of the workshop model	Principles should be developed as regards to the extent of frontloading in relation to project characteristics
Set based concurrent engineering	The designers are urged to develop at least three design alternatives	A3 poster format papers for presenting design solutions to enhance communication and effectiveness of meetings.
Pull (relevant) information just-in-time	More relevant for the detailed design phase. An extended version of the model described in (Emmitt et al, 2005) suggests the use of Last Planner (Ballard, 2000)	Additional communication policies could help to accommodate this principle e.g. not to 'replay all' in emails etc.
Face to face team integration	Imbedded in the concept of the workshop model	Cross functional MDTs could be formed to ensure system compatibility
Hands on approach + integration of relevant suppliers	More relevant for the subsequent phases of detailed design. Suppliers can be invited to participate in the workshops.	Mock-ups can be built (physically or virtually) by the designers and contractor representatives in cooperation with relevant suppliers (as MDTs).
Establish a learning culture	The model does not specifically accommodate this principle	Regular 'Kaizen' sessions could be held for continuous improvement
Standardize process, skills and components	With further development the workshop model could become the framework for a standardized process	Standardization of skills and components is more relevant within a broader conception of Design management encompassing organizational management within each professional firm.

Finally the characteristics of value and the client complexity should be addressed, which leads to the challenge of predicting the future and understanding the 'drivers' for client values in order to predict change in the value system. There are basically two approaches to this problem; (1) either

to increase knowledge to qualify a forecast and anticipate changes e.g. use of stakeholder analysis and scenario building or (2) to accept the unknowns and incorporate adaptability/flexibility in design and the use of the "last responsible moment" principle. Of course design changes are not only imposed by the client, but are also

inevitable due to the nature of creative problem solving. Change should be embraced with a positive attitude and systematic change management (London et al, 2005).

CONCLUDING COMMENTS

This paper argues that in order to adopt LPD principles in construction design management some tailoring must be done, in particular regarding client complexity and the concept of value, which is the center of attention in the workshop method proposed. The findings of a case-study of applying the workshop method suggests the importance of a strong 'system integrator', the ability of the participants to explore alternatives and make decisions, the importance of means for efficiency in meetings

within a teamwork approach, the importance of policy deployment, the value of early involvement of production orientated participants and finally the value of frontloading the process, though the extent of frontloading should be carefully considered. All which are in accordance with TPDS principles that together with considerations of the subjective nature of 'value' – which calls for systematic change management – forms the basis for further research and development of the method.

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REFERENCES

- Baines, T. Lighfoot, H. Williams, G. M. Greenough, R (2006). *State-of-the-art in lean design engineering: a literature review on white collar lean* Pr. of the Institution of Mechanical Engineers, Part B (J. of Engineering Manufacture) Vol.220
- Ballard, G. (2006) *Rethinking project definition in terms of target costing*, Pr. of the 14th annual conference on Lean Construction (IGLC-14), Santiago, Chile
- Ballard, G. (2000) *The Last Planner System of Production Control*. Ph.D. thesis, University of Birmingham, UK
- Blyth, A. Worthington, J. (2001) *Managing the brief for better design*, Spon Press
- Boyd, D. Chinyio, E. (2006) *Understanding the Construction Client*, Blackwell Publishing
- Bradley, B. (2006) *Two Concepts of Intrinsic Value*, Ethical Theory and Moral Practice 9: 111-130
- Emmitt, S. Sander, D. Christoffersen, A. K. (2004) *Implementing Value through Lean Design management* Proceedings of the 12th Annual Conference on Lean Construction (IGLC), Elsinore, Denmark
- Emmitt, S. Sander, D. Christoffersen, A. K. (2005) *The Value Universe: Defining a Value Based Approach to Lean Construction*. Proceedings of the 13th Annual Conference on Lean Construction (IGLC), Sydney, Australia, pp. 57-64.
- Hammond, J., Choo, H.J., Austin, S., Tommelein, I.D. & Ballard, G. (2000) *Integrating Design Planning, Scheduling and Control with DePlan*. Proceedings for the 8th annual conference on Lean Construction (IGLC-8), Brighton, UK
- Haque, B. and James-Moore, M. (2004) *Applying Lean Thinking to new product introduction* Journal of Engineering Design, vol. 15, no. 1, Feb.

- Jørgensen, B. (2006) *Integrating Lean Design and lean Construction: Processes and Methods* PhD Thesis, Technical University of Denmark, Department of Civil Engineering (BYG-DTU)
- Karlsson, C. and Åhlström, P. (1996) *The Difficult Path to Lean product Development* *Journal of Product Innovation Management*, 13
- Kelly, J. (2007) *Making client values explicit in value management workshops* *Journal of Construction Management and Economics* 25, pp. 435-442. April.
- Koskela, L. Ballard, G. and Tanhuanpää, V-P. (1997) *Towards lean design management* Proceedings of the 5th annual conference on Lean Construction (IGLC-5), Gold Coast, Australia
- Koskela, L.; Huovila, P. and Leinonen, J. (2002): *Design Management in Building Construction: From Theory to Practice*. *J. of Con. Research*, Vol. 3, No. 1
- London, K; Chen, J. and Bavinton, N. (2005): *Adopting reflexive capability in international briefing* *Facilities*, Vol. 23 No. 7/8, pp. 295-318
- Morgan, J. M. and Liker, J. K. (2006) *The Toyota Product Development System – Integrating People, Process, and Technology*, Productivity Press
- Perry, R. B. (1914) *The Definition of Value*, *Journal of Philosophy and Scientific Methods*. Vol. 11, No. 6. pp. 141-162, Mar. 12
- Rice, P. B. (1943) *Quality and Value*, *J. of Philosophy*, Vol. 40, No. 13 (Jun. 24)
- Sebastian, R. (2004) *Critical appraisal of design management in architecture*, *J. of Construction Research*, Vol. 5, No. 2, pp. 255-266.
- Smith, J. W. (1948) *Intrinsic and Extrinsic Good, Ethics*, Vol. 58, No. 3, Part 1. (Apr.), pp. 195-208
- Thomson, Derek S.; Austin, Simon A.; Devine-Wright, Hannah; Mills, Grant R (2003): *“Managing value and quality in design”*. *J. of Building Research & Information*, 31(5), Sept-Oct., pp. 334-345.
- Thyssen, M. H. Emmitt, S. Bonke, S. Christoffersen, A. K. (2008) *Managing Client Values in Construction Design* Proceedings of the joint conference on Information and Knowledge Management in Building CIB-W102 and Architectural Management CIB-W096, Helsinki
- Vitruvius, M. *On Architecture*, translated by Bill Thayer: <http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Vitruvius/home.html>
- Womack, J.P., Jones, D. T. and Ross, D. (1990) *The Machine That Changed the World: The Story of Lean Production*, Harper Business, New York

