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Towards a lean model for production management of refurbishment projects

ApRemodel Project

Sergio Kemmer | Lauri Koskela | Veijo Nykänen

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ApRemodel Project

Kohti peruskorjaushankkeiden tuotannonohjauksen lean-mallia.
Sergio Kemmer, Lauri Koskela & Veijo Nykänen. Espoo 2013. VTT Technology 94. 36 p.

Abstract

This is the Stage 3 Report for the ApRemodel project, which aims at improving processes for multi-occupancy retrofit by generating a lean model for project delivery. In this respect, a process-driven approach has been adopted to investigate what can be done to improve the way that retrofits projects are delivered.

An initial literature review, focused on the management of refurbishment works, revealed that the research on this matter is scarce. There are plenty of studies related to the broad refurbishment area, however only a small number refer to the way that those construction projects are delivered.

According to the literature, construction organisations have predominantly used traditional methods for managing the production of refurbishment projects. The problem is that those tools and techniques are not often appropriate to cope with the complex characteristics inherent to construction projects, especially in the case of refurbishments. Moreover, they have often not been based on a clear theoretical foundation. As a result, numerous types of waste have been identified in refurbishment projects such as waiting time, disruptions in performing tasks on site, rework, among others. This has led to unsatisfactory project performance in terms of low productivity, project delays, and cost overrun.

The first step towards better production management in refurbishment projects is recognising the complexity of the sector in order to adopt the correct approach to cope with this specific scenario. In this respect, lean construction is identified as an appropriate way to deal with the complexity and uncertainty inherent in refurbishment projects, given that this management philosophy fully integrates the conversion, flow, and value views.

This document builds on the findings from the literature review as well as evidence from case studies. Managerial practices based on lean construction principles have presented successful results in the management of complex projects. Case studies available in the literature report the feasibility and usefulness of this theoretical foundation. Moreover, the evidence from these studies show considerable potential for improving the management of refurbishment works.

A list of methods, tools, and techniques are identified. This report may be used by construction refurbishment organisations and housing associations as a starting point for improving the efficiency in managing production of refurbishment projects. To this end, partnerships between industry and academia are strongly recommended.

Although the usefulness of lean principles in complex projects is already proved, further work is needed to check what practices are best for the respective refurbishment context, as well as identifying enablers and barriers for practical adoption. Furthermore, additional studies would be also necessary to better understand the extent to which the implementation of lean philosophy might influence performance of refurbishment projects.

This report should be seen as work in progress with much more to learn, as detailed research work around the sustainable retrofit process in a lean way is further developed.

Keywords refurbishment, lean construction, complexity, management, sustainability

Kohti peruskorjaushankkeiden tuotannonohjauksen lean-mallia
Apremodel-hanke

Towards a lean model for production management of refurbishment projects.
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Tiivistelmä

Tämä julkaisu on osa Apremodel-projektia, jonka yhtenä tavoitteena on ollut parantaa asuinkerrostalojen korjaushankkeita lean-menetelmin. Korjaushankkeiden toteutuksen parantamismahdollisuuksia on tutkittu prosessilähtöisesti.

Alustava kirjallisuustarkastelu, jossa keskityttiin korjaushankkeiden suunnitteluun ja johtamiseen, osoitti sen, että teemaan liittyvää tutkimusta on tehty vähän. On olemassa paljon tutkimuksia, jotka käsittelevät yleisesti korjaustoimintaa. Varsin vähän on kuitenkin tutkittu korjaushankkeiden toteutusta ja johtamista.

Kirjallisuuslähteiden perusteella korjaustoimintaa harjoittavat yritykset ovat pääasiassa käyttäneet perinteisiä menetelmiä johtaessaan korjaushanketyömaita. Ongelma on, että käytetyt välineet ja menetelmät eivät aina kovin hyvin sovellu monimutkaisiin rakennushankkeisiin, joita erityisesti korjaushankkeet ovat. Lisäksi käytetyillä suunnittelu- ja johtamismenetelmillä ei ole kunnollista teoreettista perustaa. Tämän vuoksi on tunnistettu monenlaisia hävikkejä ja ylimääräisiä kustannuksia, kuten odotusaikoja, keskeytyksiä työmaalla, korjaustöitä jne. Tämä on johtanut tehottomaan toteutukseen, toisin sanoen heikkoon tuottavuuteen, viiveisiin ja kustannusylityksiin.

Ensimmäinen askel kohti parempaa tuotannon johtamista korjaushankkeissa on tunnistaa hankkeiden kompleksisuus, jotta oikea lähestymistapa on löydettävissä tähän prosessiongelmaan. Lean-rakentamisprosessi on havaittu keinoksi hallita korjaushankkeiden kompleksisuutta ja epävarmuutta. Lean-johtamisfilosofia integroi täysin muutos-, virtaus- ja arvontuottonäkökulmat.

Julkaisu perustuu sekä kirjallisuuskatsaukseen että tapaustutkimusten tuloksiin. Lean-menetelmiin perustuvat johtamiskäytännöt osoittavat hyviä tuloksia monimutkaisissa rakennushankkeissa. Kirjallisuudessa esitetyt tapaustutkimukset osoittavat lean-teorian käyttökelpoisuuden. Lisäksi tutkimukset osoittavat merkittävää kehittämispotentiaalia korjaushankkeiden johtamiseen.

Joukko lean-menetelmiä, työkaluja ja tekniikoita on tunnistettu. Tämä julkaisu on käyttökelpoinen korjaustoimintaa harjoittaville yrityksille ja vuokratalojen omistajille korjaushankkeiden kehittämiseen lähtökohdaksi. Yhteistyötä rakennusteollisuuden ja tutkijoiden kesken tulisi jatkaa.

Vaikka lean-periaatteiden käyttökelpoisuus monimutkaisissa projekteissa on osoitettu, jatkotyötä tarvitaan arviointiin, mitkä käytännöt soveltuvat erilaisiin hankkeisiin ja myös tunnistamaan käytännön mahdollisuuksia ja esteitä. Lisätutkimukset olisivat myös tarpeellisia, jota ymmärrettäisiin, kuinka paljon korjaushankkeiden tehokkuutta on mahdollista parantaa lean-periaatteiden avulla.

Julkaisu tulisi nähdä yhtenä vaiheena kehityksessä kohden syventävää tutkimusta kestävän korjaustoiminnan kehittämiseksi lean-periaatteilla.

Avainsanat refurbishment, lean construction, complexity, management, sustainability

Preface

This report was developed by the Salford Centre for Research and Innovation (SCRI), a research centre at The University of Salford, as part of the ApRemodel research project. ApRemodel is a collaborative project involving research organisations and government bodies in Finland. It aims to identify innovation in UK multi-occupancy retrofit and develop transferable models of best practice.

The initials phases of the ApRemodel, stages one and two, outlined the research that has been undertaken in analysing sustainable retrofit innovations in multi-occupancy buildings in UK. A socio-technical perspective was applied to understand the context of these improvements. Case studies were carried out to identify innovations in the UK's retrofit sector as well as to assess their possible adoption within a Finnish context.

This is the Stage 3 Report for the ApRemodel project, which aims at improving processes for multi-occupancy retrofit by generating a lean model for project delivery. In this respect, a process-driven approach has been adopted to investigate what can be done to improve the way that retrofits projects are delivered.

The main objectives of the report were:

- To identify the current methods adopted by industry to the management of refurbishment works
- To set the appropriate theoretical foundation to guide practical experimentation
- To recommend lean practices to the management of refurbishment works.

This report may used by construction refurbishment organisations and housing associations as a starting point for improving the efficiency in managing production of refurbishment projects. To this end, partnerships between industry and academia are strongly recommended.

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List of symbols

SCRI	Salford Centre for Research and Innovation
DECC	Department of Energy & Climate Change
BIM	Building Information Modeling
CPM	Critical Path Method
PERT	Programme Evaluation and Review Techniques
TFV	Transformation / Flow / Value
CLIP	Construction Lean Improvement Programme
BRE	Building Research Establishment
PSD	Production System Design
LOB	Line of balance
CLG	Communities and Local Government
TVD	Target Value Design
IGLC	International Group for Lean Construction
LPS	Last Planner System™
PPC	Percentage Plan Completed

1. Introduction

The Climate Change Act (DECC, 2008) legislates that the carbon emissions in the United Kingdom are to fall by no less than 80% (by comparison with a 1990 baseline) by 2050. It is known that the built environment is responsible for almost 50% of carbon dioxide emissions (Itard et al., 2008).

Given that a considerable amount of buildings, estimated at approximately 70% (Ravetz, 2008; Kelly 2009) that will be standing in 2050 have already been built, it is safe to say that the refurbishment process of the existing stock has a crucial role to meet sustainable targets.

It is also generally admitted that the degree of complexity and uncertainties in refurbishment projects is higher than in new build (Egbu et al., 1996). This scenario offers an interesting opportunity to apply lean practices in order to deal with the complexity and uncertainties inherent to those projects.

This report advocates that the production management of refurbishment projects needs an appropriate approach, specifically tailored and in line with lean tenets, to be able to cope with the complexity and uncertainty inherent to those projects, hence increasing the efficiency of the production system, e.g., lead time compression and disruption minimization.

Following this line of thought, this report presents evidence from secondary case studies in order to illustrate that managerial practices following lean principles have been successfully used for managing complex construction projects. Encouraging results have been reported by using those methods, tools, and techniques.

The lean practices identified in these case studies and those identified during the literature review are suggested as a starting point for increasing efficiency in the production management of refurbishment projects. Construction refurbishment organisations and housing associations should test the methods, tools, and techniques in their projects in order to enable a development of a model for managing refurbishment projects based on lean concepts.

The impacts of this research are both theoretical and practical. With respect to theory, lean practices can be tailored through an appropriate understanding of the characteristics of refurbishment projects. In practical terms, the benefits encompass aspects ranging from the ability to address environmental issues to the improvement of industrial competitiveness and customer satisfaction.

Finally, it should be mentioned that this study focuses on the production management of refurbishment projects. Although the authors of this report recognise the importance in improving other project domains such as design, procurement, supply chain, and operation, for instance, they have chosen production because it has not been properly addressed in the prior research and also for the opportunity for considerable improvements available in this area.

1.1 Questions driving research

The report considered the literature on production management in order to investigate the way that refurbishment organisations have been managing production and also to examine the extent to which this process can be improved through the application of concepts derived from lean construction theory. The questions below summarize the main aims for developing this report.

- What are the current methods adopted by refurbishment organisations to the production management of refurbishment projects? Are they appropriate?
- Is there a better way to manage production of refurbishment works? What kind of improvements could be achieved in this area?
- What are the lean practices suitable to deal with production management of refurbishment projects?

1.2 Research aim

The aim of this report is to improve processes for multi-occupancy retrofit by generating a lean model for project delivery.

1.3 Research objectives

- To identify the current methods adopted by industry to the management of refurbishment works
- To set the appropriate theoretical foundation to guide practical experimentation
- To recommend lean practices to the management of refurbishment works.

2. A missing link in refurbishment's research agenda

In defining refurbishment, this report will follow the definition stated by Egbu et al. (1998) who say that "*refurbishment refers to such works as improvement, adaptation, upgrading, rehabilitation, restoration, modernization, conversion, retrofit, and repair which are carried out on existing buildings for a variety of reasons. This definition, however, excludes such works as cleaning, decorating, and emergency maintenance work*."

In general, refurbishment can be considered as a subject that has been extensively addressed by researchers. Studies undertaken involve topics that vary considerably in terms of research focus. For instance, there is research delving into the analysis of the building stock and its importance (Kohler and Hassler, 2002; Itard et al., 2008), the refurbishment demand and cost implications (Aikivuori, 1996; Johnstone, 2001; Chau et al., 2003), cost modelling (Lehtonen and Kiiras, 2010), the use of information technology (Okoroh and Torrance, 1999; Caccavelli and Gugerli, 2002; Dulung, 2007; Ho, 2009; Ho and Fischer, 2009); the engagement and perspectives of users in refurbishment projects (Holm, 2000; Miller and Buys, 2008; Ho, 2009; Ho and Fischer, 2009).

In addition, due to the important role that refurbishment projects plays in meeting sustainability targets, a recent increase in the amount of research aiming at better understanding the refurbishment sector as well as improving the way that those projects are designed, procured, built, and operated is also found in the literature (Itard and Meijer, 2008; HM Government, 2010; HM Government, 2011; Mansfield, 2009; Mansfield, 2011).

Despite the vast number of research initiatives designed to better understand refurbishment sector aimed at improving its performance, the specific topic of the management of refurbishment works has not been addressed properly. Studies on practices applied to the management of this complex environment are scarce.

In the next section, more details will be provided regarding the research on the production management of refurbishment projects. The information was gathered through a literature review that sought to look at research focused on how refurbishment works are traditionally performed. Problems encountered in refurbishment projects are also mentioned.

3. The traditional approach to the production management of refurbishment projects and its practical implications

The literature on the management of refurbishment projects is scarce. There are few studies reporting the way that construction companies have been managing production in such projects. The material produced by Egbu (1994), Egbu (1995), Egbu et al. (1996), Egbu (1997), Egbu et al. (1998), and Egbu (1999) represent the most wide-ranging analysis in the management of refurbishment works.

The study developed by Egbu (1994) delves into aspects concerning to the management of refurbishment works within the UK construction industry. The analyses carried out by Egbu (1994) comprise different factors. For instance, he identified cost control, dust control, the influence of tenants on the regular progress of the works, and variation/change orders to the works as the most difficult refurbishment characteristics faced by managers. Besides, variation/change orders to the works, keeping the site tidy, cost control, maintaining site safety & welfare standards, and programming and scheduling were identified as the most frequently occurring characteristics in managing refurbishment work.

Egbu (1995) also seeks to understand the degree of difficulty associated with managing refurbishment tasks. Forecast and planning, analysis of project risks and uncertainty, and competitive tendering were perceived as the most difficult management tasks in refurbishment projects

Egbu et al. (1996) and Egbu et al. (1998) identify the managerial practices used by refurbishment organisations. These studies show clearly that production planning and control in refurbishment projects has used traditional techniques such as Critical Path Method (CPM), Programme Evaluation and Review Techniques (PERT), and Gantt charts.

Some could contend that Egbu's research is outdated, implying that the management of refurbishment works has improved since then. However, there is no evidence of this; on the contrary, there are some examples that show that it has not. A recent study developed by Henrich (2009) shows clearly that the practices applied to manage production in refurbishment projects remain inappropriate. As a result of this approach to project management, the project performance is often unsatisfactory.

Henrich (2009) conducted an analysis in two construction companies based in Greater Manchester to identify cases of low performance and waste incidence at construction sites. Both companies investigated were carrying out refurbishment projects. The first case study was a transformation of a 4 storey old mill into a block of 180 residential apartments. The second one was a regeneration program funded by a government association comprising 600 houses.

Findings from those case studies confirm that traditional planning approaches are still the basis for the production management. For instance, planning is centralized and contains excessive details at early stages. There is a lack of involvement of people (managers, subcontractors, suppliers, labourers, etc.) in the creation of plans and the CPM based software packages are used to define the critical path and estimate project duration.

In addition, managers use pre-estimated plans to push activities to the production regardless the system status and the communication between planning and production is done in a one-way fashion. Besides, there is no evidence of a continuous improvement programme implemented on site (Henrich, 2009).

As a result of the use of inefficient production management methods, Henrich (2009) identifies several types of waste within those two refurbishment projects. They refer to waiting time, the use of wrong equipment, rework, unnecessary transport, double handling, space conflicts between materials, equipment and assembly crews, and disruptions during refurbishment works. The wastes resulted in low productivity, project delays, and tenant's annoyance.

Problems in managing refurbishment projects have been also identified in Finland. For instance, Ruohomäki (2006) reports challenges faced during the planning of a renovation building in East Finland such as the lack of shared understanding of the project team, missing leadership, and weak communication.

The research carried out by Naaranoja and Uden (2007) involved four renovation projects and reveals that problems such as time and cost overrun, defective work, and failure in fulfil customer requirements. The use of inefficient project management systems is pointed out by the researchers as one of the reasons for the problems encountered in those construction projects.

In conclusion, as pointed out by Henrich (2009), the construction industry has been using either outdated production methods or using them in a wrong context. As a result, those methods lead to production wastes and a decrease in project performance.

The argument made by Henrich (2009) brings to the discussion the importance of understanding project context in order to devise an appropriate approach to cope with it. In line with this, Egbu et al. (1998) also stress that "*the process of planning should be adjusted to fit project characteristics*".

The next section summarizes the characteristics of refurbishment projects with the purpose of recommending the appropriate theoretical basis to be used in the production management of these types of construction projects.

4. The importance in recognising refurbishment characteristics

4.1 Characteristics of refurbishment

Refurbishment works have different features in comparison with new projects. Many authors point out the main characteristics and issues related to refurbishment projects:

- The management of refurbishment works is complex, highly specialized, and contains elements of works which are unique to refurbishment and different from new building work (Egbu et al., 1996);
- Refurbishment is more difficult to manage, with a higher level of risk and uncertainty than new build (Egbu, 1997; Egbu et al., 1998);
- Small labour intensive operations scattered throughout the existing buildings, often with tenants in occupation (Quah, 1992; Ho and Fischer, 2009);
- Lack of "as built" drawings to guide designer and builder (Quah, 1992);
- Unpredictability, where the extent and problems of the work are not discovered until demounting and stripping work have commenced (Quah, 1992).

Undoubtedly, the management of refurbishment projects is complex. Egbu (1995) recognised it and pointed out that those projects need appropriate managerial methods. Egbu et al. (1998) also argued that "*refurbishment works demand an ability to deal with non-continuous and complex processes*".

Actually, the subject of project complexity has been focus of several studies (Baccarini, 1996; Laufer et al., 1996; Williams, 1999; Beckerman, 2000; Bertelsen, 2003). Those authors recognize the difficulty that construction industry has to deal with the increasing complexity in construction projects. They also pointed out the need of appropriate managerial systems to cope with such complex environments.

Baccarini (1996) points out integration as a way to deal with this scenario. Following the same line of thought, Laufer et al. (1996) recommend a project management style based on elements such as integration, systemic management, simultaneous management, and the use of high-tech information technology.

4.2 Lean construction as a way forward

The lean philosophy is argued as an appropriate way to deal with the complexity and uncertainty inherent to refurbishment projects, given that this management philosophy fully integrates the transformation, flow and value views. The traditional conceptualization of engineering looks just the “conversion” aspects of the project. However, it is necessary move from a conception of production solely in terms of transformation of inputs to the TFV (Transformation/Flow/Value) concept of production (Koskela, 2000). Table 1 shows the integrated TFV view on production.

Table 1. Integrated TFV view on production (Koskela, 2000).

	Transformation view	**Flow view**	**Value generation view**
Conceptualization of production	As a transformation of inputs into outputs	As a flow of material, composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through fulfilment of his requirements
Main principles	Getting production realized efficiently	Elimination of waste (non-value-adding activities)	Elimination of value loss (achieved value in relation to best possible value)
Methods and practices (examples)	Work breakdown structure, MRP, Organizational Charts	Continuous flow, pull production control, continuous improvement	Methods for requirements capture, Quality Function Deployment
Practical contribution	Taking care of what has to be done	Taking care that what is unnecessary is done as little as possible	Taking care that customer requirements are met in the best possible manner
Suggested name for practical application of the view	Task management	Flow management	Value management

Several studies in construction management have been considering this conceptual framework to design and manage production systems in a more systemic perspective (Howell and Ballard, 1999; Lean Construction Institute, 1999; Ballard et al., 2001; Schramm et al., 2004; Alves et al., 2006; Schramm et al., 2006; Ballard, 2008).

Moreover, lean philosophy has a better approach regarding waste in comparison with traditional management. It is largely acknowledged that the seven types of wastes identified by Ohno (1988) underpin lean principles. Waste reduction is primary in lean systems. In addition, Koskela (2004) argue that there is an eighth type of waste, which he nominated as “making-do”. It refers to situations where the production starts without all prerequisites necessary to perform the task, and also when works on site continue even when any of those requirements has ceased.

Lean theory also presents a set of appropriate methods, tools, and techniques such as Last Planner System™, Target Value Design, visual management, line of balance, kanban, andon, among others, which have already been successfully implemented in construction projects.

However, while lean theory has been well tested in new construction projects, in the refurbishment sector the same level of research has not been undertaken. In fact, there are few practical examples in the literature of lean initiatives to improve the production performance of refurbishment projects.

Horman et al. (2003) discuss the use of buffers in production planning and control in the Pentagon Renovation Project. The planning method used in the project segmented it into small batches to improve production workflow. Ho and Fischer (2009) suggest an automated method to identify interactions between tenants and crews in renovations in order to reduce disruptions on site.

The study conducted by Lahtinen et al. (2009) is also an example of improvements made in a renovation project through the consideration of lean principles. Despite the fact that the term lean is not mentioned in the article, it is easy to identify overlaps between the methods applied in the study and the lean tenets.

The intervention implemented by Lahtinen et al. (2009) is characterised by the user's engagement in the renovation process, the formation of a multi-disciplinary team in order to bring different perspectives to the project environment, and the use of several channels of communications between users and project team (e.g. informative meetings, visits to the construction site, webpages containing project information such as schedules, photographs of the building site at various phases of the renovation, etc.).

An initiative named Construction Lean Improvement Programme (CLIP), sponsored by the Department of Trade and Industry and developed by the Building Research Establishment (BRE), has been also adapting lean tools and techniques for use in the refurbishment projects in order to improve efficiency in site operations (CLIP, 2003).

What is generally encountered in the literature are examples of lean implementation in construction projects that have similar characteristics in comparison with refurbishment projects. For example, the studies carried out by Schramm et al. (2006) and Cuperus et al. (2010) illustrate an appropriate and innovative approach for managing production system of complex construction projects. They have achieved significant results through the use of managerial practices in line with the lean tenets. For instance, Cuperus et al. (2010) report an impressive reduction (more than 50%) in the fit-out time per dwelling in a housing project. Schramm et al. (2006) increased transparency and effectiveness of plans.

Several methods and tools in line with the lean tenets were implemented in the case studies carried out by Schramm et al. (2006) and Cuperus et al. (2010). For example, Last Planner System, production system design, line of balance, etc.

The difference of the lean approach used in those case studies (Schramm et al., 2006; Cuperus et al., 2010) in comparison with the traditional managerial practices normally used by the refurbishment construction companies is clear. While the latter approach has led to unsatisfactory results, the lean approach presents en-

couraging outcomes. This fact highlights once again the importance of using a lean philosophy as a theoretical base to guide production management of construction projects.

Also, the research conducted by Schramm et al. (2006) points out the importance in adapting managerial practices according to projects characteristics. For instance, due the considerable number of change orders demanded by clients, even after the production stage had started, Schramm et al. (2006) suggest the early involvement of client representatives in the development of the production system design in order to make them aware of the impact of their changes. They also recommend the development of the production system design in stages with a gradual evolution in planning detailing.

Therefore, similarly to the study conducted by Schramm et al. (2006), which sought to adapt a model originally created for designing production systems of low-income housing projects (Schramm et al., 2004) to the context of complex projects, the research on the management of refurbishment works should also aim at adjusting the implementation of lean practices to its context.

Although the studies conducted by Schramm et al. (2006) and Cuperus et al. (2010) do not refer directly to refurbishment projects, these case studies represent construction projects with complex characteristics, akin to the refurbishment context. Clearly, lessons can be learned from those experiences in order to improve the way that the management of production in refurbishment projects is performed.

5. Exploring opportunities of lean implementations in the ApRemodel research

5.1 Introduction

The ApRemodel project looks specifically at multi-occupancy dwellings. The English Housing Condition Survey (CLG, 2011) identifies that number of multi-occupancy dwellings is considerable (more than 4 million), even though it represents a minor group in the English housing stock, only 19% in comparison with other types of dwellings. They are also divided in 3 main types (converted, low rise, and high rise flats).

The questions that came out of those figures are: does every lean practice suit to any type of multi-occupancy dwelling? Presumably, there are different approaches to different projects.

Therefore, it is worth to investigate the usefulness of the lean practices across the different types of multi-occupancy dwellings. Following below the managerial practices selected from the literature review:

- Collaborative Design (1)
- Target Value Design (2)
- Production System Design (3)
- Last Planner System (4)
- Line of balance (5)
- Visual Management (6)
- Cellular Manufacturing (7)
- Multiskilling (8)
- Prefabrication / Standardisation (9)
- Mass customisation (10)
- Benchmarking (11).

In the next section, the managerial practices suggested are briefly introduced.

5.2 Lean practices at a glance

This section gives a brief overview of the management practices previously identified to introduce those that have been successfully applied in construction projects and that might be useful in the refurbishment context.

At the end of this report, a non-exhaustive list of references illustrating the concepts and practical applications of each managerial practice in the construction sector is provided for further details.

5.2.1 Collaborative design

In order to deal with the complexity inherent to construction projects, a collaborative approach to the design process is necessary. In practical terms, this means different disciplines working together in a collaborative fashion. To this end, teamwork and cooperation are vital to achieve better results.

This assumption leads to a basic question, which is: how to promote an effective collaboration? A process methodology named Integral Design (Zeiler et al., 2009) is proposed to support the integration of different disciplines involved in the design process, hence improving design quality, reducing failures and cost.

Through the adoption of a function/aspect-oriented strategy, which involves the use of a framework comprising the functions and aspects that the design has to fulfil, besides the solution alternatives, the design process became more structured and transparent (Zeiler and Savanovic, 2008).

5.2.2 Target Value Design

The implementation of the Target Costing in the design of construction projects is defined by Target Value Design (TVD). According Ballard (2009) TVD is *"a management practice that drives design to deliver customer values, and develops design within constraints"*.

Usually, the cost of a building is defined based on its design. TVD reverses this logic by defining cost before design (Pennanen et al., 2011). The budget set upfront cannot be exceeded. As a result, the design should innovate to comply with the target set.

The TVD approach has features that can be very useful in refurbishment projects. For instance, the client's engagement to define the target value, the use of cross functional teams to improve the interface between product and process, besides the consistent pursuit of waste reduction during design.

5.2.3 Production System Design

According Ballard et al. (2001) *"the first task in any productive endeavour is production system design, which extends from global organization to the design of operations"*. They also stress that production system design (PSD) has to tackle

the three goals of production systems: do the job, maximize value, and minimize waste.

Slack et al. (1997) argue that the objective of the PSD is to debate and convert the planned production strategy into a set of decisions, forming the structure that will manage the different activities. Ballard et al. (2001) contend that PSD should also create the appropriate conditions for control and improvement.

5.2.4 Last Planner System™

The Last Planner System[1] (LPS) aims to produce reliable workflow and stabilises the project. According Ballard (2000), the LPS *"is a philosophy, rules and procedures, and a set of tools that facilitate the implementation of those procedures".*

Based on Ballard (1997; 2000) and Ballard and Howell (2003), Koskela et al. (2010) summarize the five main integrated elements of LPS:

- Master Plan – this is to obtain a general plan and identify all the work packages for the whole project showing the main activities, their duration and sequence;
- Phase Planning – it is about dividing the master plan into various phases aimed to developing more detailed work plans and provide goals that can be considered targets by the project team. Phase planning is a bridge between the master plan and look ahead planning;
- Look Ahead Planning – this is about focusing management attention on what is supposed to happen at some time in the future, and to encourage actions in the present that cause that desired future;
- Weekly Work Plan – this is the collaborative agreement in respect of production tasks for the next day or week via weekly meetings. Weekly meetings help to plan the work that will be done in the next week bearing in mind the work that is being done now and in the knowledge of the work that is ready to be done. The WWP meeting covers the weekly plans, safety issue, quality issue, resources, construction methods, and any problems that occur in the field;
- Percent Plan Completed and analysis of reasons for non-completed tasks – this is about improving the project planning by continual assessment and learning from failure. Percent Plan Completed (PPC) is a measure of the proportion of promises made that are delivered on time. PPC can be calculated as the number of activities that are completed as planned divided by the total number of planned activities, and it is presented as a percentage.

[1] The Last Planner System is a registered trademark of Lean Construction Institute.

5.2.5 Line of Balance

The line of balance (LOB) is a tool for project planning and control that provides great visibility for the flow of work in a construction site. The LOB depicts information related to when, where and what activities are done at any time as well as activity batch size, pace, and buffers between different crews.

Besides making workflows more transparent to those managing a project, this tool can serve as a means to simulate and discuss different alternatives and strategies to sequence activities in the long run.

5.2.6 Visual management

According Tezel (2011) visual management is "*the managerial strategy of employing visual (sensory) tools and aids in close-range communication at a workplace to increase the self-management ability of the workforce*". The use of visual tools makes possible the reduction of waste and variability in the production system.

Visual management plays a fundamental role in lean systems. According Liker (2004), it enables people to look at the processes and quickly identify if there is any deviation from the standard. It provides operative crews and production managers the opportunity of learning.

5.2.7 Cellular manufacturing

Production cell is largely used in the manufacturing industry (Hyer and Brown, 1999). It is an operation management approach that seeks to improve efficiency in production systems through the exploration of the similarities encountered in parts of the production process, especially those that have the same processing requirements (Shafer and Rogers, 1991).

Hyer and Brown (1999) define it as *"dedicating equipment, and materials to a family of parts or products with similar processing requirements by creating a workflow where tasks and those who perform them are closely connected in term of time, space, and information".*

According Santos et al. (2002) this alternative method to organise production offers the possibility to move from an inflexible and repetitive mass production approach to a more flexible small-lot production. They stress that *"cell manufacturing encapsulates most lean production practices within a single environment"*.

Factors such as multi-skilling, reduced set-up times, small transfer batch size, and the presence of visual controls support the establishment of production cells (Hyer and Brown, 1999). The benefits in adopting production cells include high quality, productivity increase, shorter setup time, in-process inventory, and lead-time, besides cost savings.

5.2.8 Multiskilling

Multiskilling is defined by workers who possess several skills that allow them to execute different tasks. This strategy has proved beneficial for both workers and construction companies. According Wang et al. (2009) it can increase productivity, quality, and continuity of work, and also reduces skill shortages through better utilization of the current labour force.

In respect of refurbishment projects, the use of multi-skilled workers or teams can be very useful. The use of multi-skilled teams supports continuous work flow improving the efficiency of the production system, for instance, reducing disruptions on site and compressing the project lead time.

5.2.9 Prefabrication and standardisation

It is largely acknowledged that prefabrication and standardisation in construction processes lead to increased quality and reductions of cost and time (Goodier and Gibb, 2007). Therefore, it makes sense to have this approach to the refurbishment sector. The question that remains is to what extent those strategies can be applied to this specific sector. The detailed issues surrounding this industrial approach should be better investigated in retrofit projects.

5.2.10 Mass customisation

In simple terms, mass customisation has two mains objectives: offer product variety while maintaining process efficiency. Hart (1995) presents a thorough definition stressing that it consists of *"cutting-edge management methods and tools that give companies the ability to produce customised, affordable, high-quality goods and services, but with the shorter cycle times and lower costs historically associated with mass production and standardisation"*.

The mass customisation approach can be useful to the refurbishment sector. The unpredictability associated to such projects can lead to a project environment similar to what is found in a customisation process. Thus, pursuing the ability to cope with it in an efficient way is certainly an objective that is worth looking for.

5.2.11 Benchmarking

As defined by Camp (1989), benchmarking refers to a continuous and consistent process of investigating world leaders' methods, practices, and processes, in any particular area, and implementing the best examples in order to achieve the best performance.

Benchmarking is included within the list of principles for flow process design and improvement devised by Koskela (1992). The comparison of company's current performance against the world leaders is fundamental in lean systems because it supports a culture of continuous improvement.

6. Conclusions and future research

6.1 Conclusions

This study reveals that the management of refurbishment works has not been addressed in detail in prior research. Studies on practices applied to the management of this complex environment are scarce and have lacked a theoretical underpinning. The traditional planning systems normally used by construction organisations neglect the characteristics of construction projects; hence the project performance in construction projects, including refurbishments, remains unsatisfactory.

Lean theory is the appropriate theoretical foundation to cope with complex environments like refurbishment projects. Recognising the uncertainty inherent to those projects and reducing it by using appropriate managerial practices is vital to mitigate the negative impacts that variability brings to the project environment. The methods, tools, and techniques used for production management of refurbishment projects should be based on a lean philosophy.

The examples presented in this report indicate that the use of managerial practices based on lean concepts and principles is appropriate and useful for managing production of complex construction projects. Moreover, they indicate that there is a huge potential for increasing efficiency in production systems as well as in improving project performance.

However, while the results from lean implementations are encouraging, especially in new building projects, there is a lack of practical application of lean within refurbishment sector. Clearly, there is a room for exploration as to how lean philosophy can be applied to innovate and improve the way that production management of refurbishment projects is performed.

A list of methods, tools, and techniques for managing production systems should be tested by construction refurbishment organisations and housing associations in order to improve efficiency in managing production of refurbishment projects. Based on examples from the literature, it is clear that the best way to assess the efficacy of the lean approach is experimenting. It is by practicing and experimenting that the necessary awareness to achieve a continuous improvement is developed.

Nevertheless, there are risks in experimenting new practices. These can be managed, for instance, by integrated working by industry and academy. As new ways to manage the production systems are brought to a project environment, support is required to enable people to deal with this innovative way of work.

Actions have to be taken towards a development of a lean model for managing production in refurbishment projects. The following is suggested:

- To engage industry
    - Partnerships with refurbishment organisations and housing associations in order to test the managerial practices within different refurbishment projects
    - Workshops aiming at introducing the lean theory and the managerial practices suggested, besides fostering discussions on the usefulness and feasibility in applying lean in refurbishment projects
    - Case studies aiming at testing the lean model for managing production in refurbishment projects and obtaining a baseline to enable future comparisons
- To re-design the lean model based on the contributions acquired from the case studies (industry feedback)
- To deliver a lean model for managing production in refurbishment projects
- To develop an execution plan to scale the lean model to industry.

6.2 Future research

Further work is needed in order to better understand the characteristics of refurbishment projects and also to comprehend how these features affect the implementation of the lean model in such projects. Some initial questions for discussion are presented in the following:

- What kinds of wastes exist in the production management of refurbishment projects? How prevalent are they?
- To what extent will the adoption of lean practices influence the project performance of refurbishment projects?
- What are the enablers and barriers for the adoption of lean practices in refurbishment projects?
- What are the implications for both AEC industry and academia in applying a lean approach for the production management of refurbishment projects?
- How can the approaches be scaled up to the wider industry?

References

Aikivuori, A. 1996. Periods and demand for private sector housing refurbishment. Construction Management and Economics, Vol. 14, pp. 3–12.

Alves, T. C. L., Tommelein, I. D., Ballard, G. 2006. Simulation as tool for production system design in construction. In: Annual Conference of the International Group for Lean Construction, 14. Santiago. Proceedings.

Baccarini, D. 1996. The concept of project complexity – a review. International Journal of Project Management, Vol. 14, No. 4, pp. 201–204.

Ballard, G. 1997. Lookahead planning, the missing link to production control. In: Annual Conference of the International Group for Lean Construction, 5. Gold Coast. Proceedings.

Ballard, G. 2000. The last planner system of production control. Thesis. School of Civil Engineering of Faculty of Engineering of the University of Birmingham. Birmingham, UK. 192 p.

Ballard, G. 2008. The lean project delivery system: An update. Lean Construction Journal. pp. 1–19. Available at: http//:www.leanconstructionjournal.org.

Ballard, G. 2009. Target value design. Lean Construction Institute. University of California, Berkeley. Available at: http://p2sl.berkeley.edu/2009-05-26/Glenn%202008-07-29%20=%20Target%20Value%20Design.pdf.

Ballard, G., Howell, G. 2003. An update on Last Planner. In: Annual Conference of the International Group for Lean Construction, 11. Blacksburg, Proceedings.

Ballard, G., Koskela, L., Howell, G., Zabelle, T. 2001. Production System Design in construction. In: Annual Conference of the International Group for Lean Construction, 9. Singapore. Proceedings.

Beckerman, L. P. 2000. Application of complex systems science to systems engineering. Systems Engineering, Vol. 3, No. 2, pp. 96–102.

Bertelsen, S. 2003. Complexity – construction in a new perspective. In: Annual Conference of the International Group for Lean Construction, 11. Blacksburg. Proceedings.

Caccavelli, D., Gugerli, H. 2002. TOBUS – A European diagnosis and decision-making tool for office building upgrading. Energy and Buildings, Vol. 34, pp. 113–119.

Camp, R. C. 1989. Benchmarking: The search for industry best practices that lead to superior performance. ASQC Quality Press, Milwaukee. 299 p.

Chau, K. W., Leung, A. Y. T., Yiu, C. Y., Wong, S. K. 2003. Estimating the value enhancement effects of refurbishment. Facilities, Vol. 21, No. 1/2, pp. 13–19.

Communities and Local Government (CLG). 2011. English Housing Survey. Housing Stock Summary Statistics 2009. Department for Communities and Local Government, London, July.

Constructin Lean Improvement Programme (CLIP). 2003. Profit from process improvement. Construction Excellence. Building Research Establishment (BRE). Report – Case studies – Volume 1 [online]. Available at: http://www.bre.co.uk/page.jsp?id=355.

Cuperus, Y., Wamelink, H., Resodihardjo, G. 2010. Reducing fit-out time in a Netherlands housing project. In: Annual Conference of the International Group for Lean Construction, 18. Haifa. Proceedings.

Department of Energy & Climate Change (DECC). 2008. Climate Change Act. Available at: http://www.decc.gov.uk/en/content/cms/legislation/cc_act_08/cc_act_08.aspx.

Dulung, A. Z. A. 2007. Computer aided decision support system for the selection of subcontractors in building refurbishment works. Thesis, School of Design and Environment, National University of Singapore, Singapore.

Egbu, C. O. 1994. Management education and training for refurbishment work within the construction industry. Thesis, The Department of Civil Engineering and Construction, The University of Salford, Salford, UK.

Egbu, C. O. 1995. Perceived degree of difficulty of management tasks in construction refurbishment work. Building Research and Information, Vol. 23, No. 6, pp. 340–344.

Egbu, C. O. 1997. Refurbishment management: challenges and opportunities. Building Research and Information, Vol. 25, No. 6, pp. 338–347.

Egbu, C. O. 1999. Skills, knowledge and competencies for managing construction refurbishment works. Construction Management Economics, Vol. 17, pp. 29–43.

Egbu, C. O., Young, B. A., Torrance, V. B. 1996. Refurbishment management practices in the shipping and construction industries – lessons to be learned. Building Research and Information, Vol. 24, No. 6, pp. 329–338.

Egbu, C. O., Young, B. A., Torrance, V. B. 1998. Planning and control processes and techniques for refurbishment management. Construction Management and Economics, Vol. 16, pp. 315–325.

Goodier, C., Gibb, A. 2007. Future opportunities for offsite in the UK. Construction Management and Economics, Vol. 25, pp. 585–595.

Hart, C. W. L. 1995. Mass customization: conceptual underpinnings, opportunities and limits. International Journal of Service Industry Management, Vol. 6, No. 2, pp. 36–45.

Henrich, G. 2009. Development of a tool for diagnosing production management efficiency on construction sites. Thesis, School of the Built Environment, The University of Salford, Salford.

HM Government 2010. Final Report. Low Carbon Construction – Innovation and growth team. Autumn.

HM Government 2011. Action Plan. Government response to the Low Carbon Construction – Innovation and Growth Team. Report. June.

Ho, P. 2009. An automated method to identify occupant interactions in renovations of occupied buildings. Technical Report 185. Center for Integrated Facility Engineering, Stanford University, Stanford.

Ho, P., Fischer, M. 2009. An examination of current practices in identifying occupant interactions in renovations projects. Working Paper 121. Center for Integrated Facility Engineering, Standard University, Stanford.

Holm, M. G. 2000. Service management in housing refurbishment: a theoretical approach. Construction Management and Economics, Vol. 18, pp. 525–533.

Horman, M. J., Messner, J. I., Riley, D. R., Pulaski, M. H. 2003. Using buffers to manage production: a case study of the Pentagon Renovation Project. In: Annual Conference of the International Group for Lean Construction, 11., Blacksburg. Proceedings.

Howell, G., Ballard, G. 1999. Design of Construction Operations. LCI White Paper 04. January 9. Available at: http://www.leanconstruction.org.

Hyer, N. L., Brown, K. A. 1999. The discipline of real cells. Journal of Operations Management, Vol. 17, pp. 557–574.

Itard, L., Meijer, F. 2008. Towards a sustainable northern European housing stock. Figures, facts and future. Report, Delft Centre for Sustainable Urban Areas, Delft University of Technology.

Itard, L., Meijer, F., Vrins, E., Hoiting, H. 2008. Building renovation and modernisation in Europe: state of the art review. Final report. OTB Research Institute for Housing, Urban and Mobility Studies. Delft University of Technology. Netherlands.

Johnstone, I. M. 2001. Periodic refurbishment and reductions in national cost to sustain dwelling services. Construction Management and Economics, Vol. 19, pp. 97–108.

Kelly, M. J. 2009. Retrofitting the existing UK building stock. Building Research and Information, Vol. 37, No. 2, pp. 196–200.

Kohler, N., Hassler, U. 2002. The building stock as a research project. Building Research & Information, Vol. 30, pp. 226–236.

Koskela, L. 1992. Application of the new production philosophy to construction. Technical Report No. 72. Stanford University, Centre for Integrated Facility Engineering, USA. 75 p.

Koskela, L. 2000. An exploration towards a production theory and its application to construction. Espoo. Technical Research Centre of Finland. VTT Publication 408. 296 p. Available at: http://www.vtt.fi/inf/pdf/publications/2000/P408.pdf.

Koskela, L. 2004. Making-do – The eight category of waste. In: Annual Conference of the International Group for Lean Construction, 12. Copenhagen. Proceedings.

Koskela, L., Stratton, R., Koskenvesa, A. 2010. Last planner and critical chain in construction management: comparative analysis. In: Annual Conference of the International Group for Lean Construction, 18. Haifa. Proceedings.

Lahtinen, M., Salonen, H., Lappalainen, S., Huttunen, J., Reijula, K. 2009. Renovation of a “Sick Building”: The challenge of attaining the confidence of occupants. American Journal of Industrial Medicine, Vol. 52, pp. 438–445.

Laufer, A., Denker, G. R., Shenhar, A. J. 1996. Simultaneous management: the key to excellence in capital projects. International Journal of Project Management, Vol. 14, No. 4, pp. 189–199.

Lean Construction Institute (LCI). 1999. Work Structuring. LCI White Paper 5. June. [online] Available at: http://www.leanconstruction.org.

Lehtonen, J. L., Kiiras, J. M. 2010. Cost modelling in underpinning projects. Construction Management and Economics, Vol. 28, No. 9, pp. 985–995.

Liker, J. K. 2004. The Toyota Way – 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill, United States.

Mansfield, J. 2009. Sustainable refurbishment: policy direction and support in the UK. Structural Survey, Vol. 27, No. 2, pp. 148–161.

Mansfield, J. 2011. Sustainable refurbishment: some practical regulatory hurdles. Structural Survey, Vol. 29, No. 2, pp. 120–132.

Miller, E., Buys, L. 2008. Retrofitting commercial office buildings for sustainability: tenants' perspectives. Journal of Property Investment & Finance, Vol. 26, No. 6, pp. 552–561.

Naaranoja, M., Uden, L. 2007. Major problems in renovation projects in Finland. Building and Environment, Vol. 42, pp. 852–859.

Okoroh, M. I., Torrance, V. B. 1999. A model for subcontractor selection in refurbishment projects. Construction Management and Economics, Vol. 17, pp. 315–327.

Ohno, T. 1988. Toyota Production System. Beyond Large-Scale Production. Productivity Press. New York.

Pennanen, A., Ballard, G., Haahtela, Y. 2011. Target costing and designing to targets in construction. Journal of Financial Management of Property and Construction, Vol. 16, No. 1, pp. 52–63.

Quah, L. K. 1992. Comparative variability in tender bids for refurbishment and new build work. Construction Management and Economics, Vol. 10, pp. 263–269.

Ravetz, J. 2008. State of the stock – What do we know about existing buildings and their future prospects? Energy Policy, Vol. 36, pp. 4462–4470.

Ruohomäki, V. 2006. Distributed and mobile work – promoting collaboration with the Teamwork Game. In: Report on Workspace Methodologies – studying communication, collaboration and workspaces. Vartiainen, M. (ed.) Department of Industrial Engineering and Management. Laboratory of Work Psychology and Leadership. Helsinki University of Technology. BIT Research Centre.

Santos, A., Moser, L., Tookey, J. E. 2002. Applying the concept of mobile cells manufacturing on the drywall process. In: Annual Conference of the International Group for Lean Construction, 10, Gramado. Proceedings.

Schramm, F. K., Costa, D. B., Formoso, C. T. 2004. The design of production systems for low-income housing projects. In: Annual Conference of the International Group for Lean Construction, 12. Copenhagen. Proceedings.

Schramm, F. K., Rodrigues, A. A., Formoso, C. T. 2006. The role of Production System Design in the management of complex projects. In: Annual Conference of the International Group for Lean Construction, 14. Santiago. Proceedings.

Shafer, S. M., Rogers, D. F. 1991. A goal programming approach to the cell formation problem. Journal of Operations Management, Vol. 10, No. 1, pp. 28–44.

Slack, N., Chambers, S., Harland, C., Harrison, A., Johnston, R. 1997. Operations Management. Atlas. Sao Paulo.

Tezel, B. A. 2011. Visual management: an exploration of the concept and its implementation in construction. PhD Thesis. The University of Salford.

Wang, Y., Goodrum, P. M., Haas, C. T., Glover, R. W. 2009. Analysis of observed skill affinity patterns and motivation for multiskilling among craft workers in the U.S. industrial construction sector. Journal of Construction Engineering and Management, Vol. 135, No. 10, pp. 999–1008.

Williams, T. M. 1999. The need for new paradigms for complex projects. International Journal of Project Management, Vol. 17, No. 5, pp. 269–273.

Zeiler, W., Savanovic, P. 2008. Collaborative design management: Learning by doing. In: Proceedings of the joint CIB W096 Architectural Management and CIB TG49. Proceedings. Rotterdam, Netherlands.

Zeiler, W., Savanovic, P., Quanjel, E. 2009. Integral Design Method: A conceptual architectural management tool. Part 5 – Integral Design and Innovation. In: Architectural Management – International Research and Practice Emmit, S., Prins, M, den Otter, A. (ed.). Pp. 207–227.

Recommended reading

Collaborative design

Quanjel, E. M. C. J., Zeiler, W., Den Otter, A. 2010. Collaborative design workshops: explanation of an Analysing Model for Knowledge Exchange. In: Proceedings of 18th CIB World Building Congress, W096 – Special Track, CIB W096 – Architectural Management. Proceedings. Salford, United Kingdom.

Zeiler, W., Savanovic, P. 2010. Integral design workshops: organization, structure and testing. The Journal on Systemics, Cybernetics and Informatics, Vol. 8, No. 4, pp. 30–41.

Zeiler, W., Savanovic, P., Quanjel, E. M. C. J. 2006. Methodology for dynamic briefing of adaptable buildings. In: International Conference on Adaptable Building Structures. Eindhoven, Netherlands.

Zeiler, W., Savanovic, P., Quanjel, E. 2009. Integral Design Method: A conceptual architectural management tool. Part 5 – Integral Design and Innovation. In: Architectural Management – International Research and Practice Emmit, S., Prins, M, den Otter, A. (ed.). Pp. 207–227.

Target value design

Ballard, G. 2006. Rethinking project definition in terms of target costing. In: Annual Conference of the International Group for Lean Construction, 14. Santiago. Proceedings.

Ballard, G., Reiser, P. 2004. The St. Olaf College Fieldhouse Project: A case study in designing to target cost. In: Annual Conference of the International Group for Lean Construction, 12. Elsinore. Proceedings.

Pennanen, A., Ballard, G., Haahtela, Y. 2011. Target costing and designing to targets in construction. Journal of Financial Management of Property and Construction, Vol. 16, No. 1, pp. 52–63.

Production system design

Ballard, G., Koskela, L., Howell, G., Zabelle, T. 2001. Production System Design in construction. In: Annual Conference of the International Group for Lean Construction, 9., Singapore. Proceedings.

Schramm, F. K., Costa, D. B., Formoso, C. T. 2004. The design of productions systems for low-income housing projects. In: Annual Conference of the International Group for Lean Construction, 12, Elsinore. Proceedings.

Schramm, F., Rodrigues, A., Formoso, C. T. 2006. The role of production system design in the management of complex projects. In: Annual Conference of the International Group for Lean Construction, 14, Santiago. Proceedings.

Last Planner System™

Ballard, G. 2000. The Last Planner System of Production Control. Thesis. School of Civil Engineering of Faculty of Engineering of the University of Birmingham. Birmingham, UK. 192 p.

Ballard, G., Howell, G. 2003. An update on Last Planner. In: Annual Conference of the International Group for Lean Construction, 11., Blacksburg. Proceedings.

Line of balance

Kemmer, S. L., Heineck, L. F. M., Alves, T. C. L. 2008. Using the line of balance for production system design. In: Annual Conference of the International Group for Lean Construction, 16, Manchester. Proceedings.

Seppänen, O., Aalto, E. 2005. A case study of line-of-balance based schedule planning and control system. In: Annual Conference of the International Group for Lean Construction, 13, Sydney. Proceedings.

Soini, M., Leskelä, I., Seppänen, O. 2004. Implementation of line-of-balance based scheduling and project control system in a large construction company. In: Annual Conference of the International Group for Lean Construction, 12, Copenhagen. Proceedings.

Visual management

Sacks, R., Treckmann, M., Rozenfeld, O. 2009. Visualization of work flow to support lean construction. Journal of Construction Engineering and Management, Vol. 135, No. 12, pp. 1307–1315.

Tezel, A., Koskela, L., Tzortzopoulos, P. 2010. Visual management in construction. Study report on Brazilian cases. Salford Centre for Research and Innovation. Research Report. The University of Salford.

Tezel, A., Koskela, L., Tzortzopoulos, P., Koskenvesa, A., Sahlstedt, S. 2011. An examination of visual management on Finnish construction sites. In: Annual Conference of the International Group for Lean Construction, 19, Lima. Proceedings.

Tezel, B. A. 2011. Visual management: an exploration of the concept and its implementation in construction. PhD Thesis. The University of Salford.

Cellular manufacturing

Mariz, R. N., Picchi, F. A., Granja, A. D., Melo, R. S. S. 2011. Broader implementations of production cells in construction considering time, space and information linkages. In: Annual Conference of the International Group for Lean Construction, 19, Lima. Proceedings.

Santos, A., Moser, L., Tookey, J. E. 2002. Applying the concept of mobile cells manufacturing on the drywall process. In: Annual Conference of the International Group for Lean Construction, 10, Gramado. Proceedings.

Multiskilling

Cuperus, Y., Wamelink, H., Resodihardjo, G. 2010. Reducing fit-out time in a Netherlands housing project. In: Annual Conference of the International Group for Lean Construction, 18, Haifa. Proceedings.

Maturana, S., Alarcon, L. F., Deprez, M. 2003. Modelling the impact of multiskilling and concrete batch size in multi-storey buildings. In: Annual Conference of the International Group for Lean Construction, 11, Blacksburg. Proceedings.

Sacks, R., Goldin, M. 2007. Lean management model for construction of high-rise apartment building. Journal of Construction Engineering and Management, Vol. 133, No. 5, pp. 374–384.

Prefabrication and standardisation

Bjornfot, A., Stehn, L. 2005. Product design for improved material flow – a multi-storey timber housing project. In: Annual Conference of the International Group for Lean Construction, 13, Sydney. Proceedings.

Hook, M. 2006. Customer value in lean prefabrication of housing considering both construction and manufacturing. In: Annual Conference of the International Group for Lean Construction, 14, Santiago. Proceedings.

Hook, M., Stehn, L. 2005. Connecting lean construction to prefabrication complexity in Swedish volume element housing. In: Annual Conference of the International Group for Lean Construction, 13, Sydney. Proceedings.

Hook, M., Stehn, L. 2008. Applicability of lean principles and practices in industrialized housing production. Construction Management and Economics, Vol. 26, pp. 1091–1100.

Lennartsson, M., Bjornfot, A., Stehn, L. 2008. Lean modular design: value-based progress of industrialized housing. In: Annual Conference of the International Group for Lean Construction, 16, Manchester. Proceedings.

Lessing, J., Stehn, L., Ekholm, A. 2005. Industrialized housing: definition and categorization of the concept. In: Annual Conference of the International Group for Lean Construction, 13, Sydney. Proceedings.

Roy, R., Low, M., Waller, J. 2005. Documentation, standardization and improvement of the construction process in house building. Construction Management and Economics, Vol. 23, pp. 57–67.

Mass customisation

Kemmer, S. L., Rocha, C. G., Meneses, L. O., Pacheco, A. V. L., Formoso, C. T. 2010. Application of lean principles to manage a customisation process. In: Annual Conference of the International Group for Lean Construction, 18, Haifa. Proceedings.

Lu, W., Olofsson, T., Stehn, L. 2011. A lean-agile model of homebuilders' production systems. Construction Management and Economics, Vol. 29, pp. 25–35.

Rocha, C. G. 2011. A conceptual framework for defining customisation strategies in the house building sector. Thesis. Postgraduate Program in Civil Engineering of the Federal University of Rio Grande do Sul. Porto Alegre, Brazil.

Benchmarking

Costa, D. B., Formoso, C. T., Kagioglou, M., Alarcon, L. F. 2004. Performance measurement systems for benchmarking in the construction industry. In: Annual Conference of the International Group for Lean Construction, 12, Copenhagen. Proceedings.

Costa, D. B., Formoso, C. T., Kagioglou, M., Alarcon, L. F., Caldas, C. H. 2006. Benchmarking initiatives in the construction industry: lessons learned and improvement opportunities. Journal of Management in Engineering, Vol. 22, No. 4, pp. 158–167.

Ramirez, R. R., Alarcon, L. F., Knights, P. 2004. Benchmarking system for evaluating management practices in the construction industry. Journal of Management in Engineering, Vol. 20, No. 3, pp. 110–117.

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Title	**Towards a lean model for production management of refurbishment projects** **ApRemodel Project**
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Abstract	This is the Stage 3 Report for the ApRemodel project, which aims at improving processes for multi-occupancy retrofit by generating a lean model for project delivery. In this respect, a process-driven approach has been adopted to investigate what can be done to improve the way that retrofits projects are delivered. An initial literature review, focused on the management of refurbishment works, revealed that the research on this matter is scarce. There are plenty of studies related to the broad refurbishment area, however only a small number refer to the way that those construction projects are delivered. According to the literature, construction organisations have predominantly used traditional methods for managing the production of refurbishment projects. The problem is that those tools and techniques are not often appropriate to cope with the complex characteristics inherent to construction projects, especially in the case of refurbishments. Moreover, they have often not been based on a clear theoretical foundation. As a result, numerous types of waste have been identified in refurbishment projects such as waiting time, disruptions in performing tasks on site, rework, among others. This has led to unsatisfactory project performance in terms of low productivity, project delays, and cost overrun. The first step towards better production management in refurbishment projects is recognising the complexity of the sector in order to adopt the correct approach to cope with this specific scenario. In this respect, lean construction is identified as an appropriate way to deal with the complexity and uncertainty inherent in refurbishment projects, given that this management philosophy fully integrates the conversion, flow, and value views. This document builds on the findings from the literature review as well as evidence from case studies. Managerial practices based on lean construction principles have presented successful results in the management of complex projects. Case studies available in the literature report the feasibility and usefulness of this theoretical foundation. Moreover, the evidence from these studies show considerable potential for improving the management of refurbishment works. A list of methods, tools, and techniques are identified. This report may used by construction refurbishment organisations and housing associations as a starting point for improving the efficiency in managing production of refurbishment projects. To this end, partnerships between industry and academia are strongly recommended. Although the usefulness of lean principles in complex projects is already proved, further work is needed to check what practices are best for the respective refurbishment context, as well as identifying enablers and barriers for practical adoption. Furthermore, additional studies would be also necessary to better understand the extent to which the implementation of lean philosophy might influence performance of refurbishment projects. This report should be seen as work in progress with much more to learn, as detailed research work around the sustainable retrofit process in a lean way is further developed.
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Nimeke	**Kohti peruskorjaushankkeiden tuotannonohjauksen lean-mallia** **Apremodel-hanke**
Tekijä(t)	Sergio Kemmer, Lauri Koskela & Veijo Nykänen
Tiivistelmä	Tämä julkaisu on osa Apremodel-projektia, jonka yhtenä tavoitteena on ollut parantaa asuinkerrostalojen korjaushankkeita lean-menetelmin. Korjaushankkeiden toteutuksen parantamismahdollisuuksia on tutkittu prosessilähtöisesti. Alustava kirjallisuustarkastelu, jossa keskityttiin korjaushankkeiden suunnitteluun ja johtamiseen, osoitti sen, että teemaan liittyvää tutkimusta on tehty vähän. On olemassa paljon tutkimuksia, jotka käsittelevät yleisesti korjaustoimintaa. Varsin vähän on kuitenkin tutkittu korjaushankkeiden toteutusta ja johtamista. Kirjallisuuslähteiden perusteella korjaustoimintaa harjoittavat yritykset ovat pääasiassa käyttäneet perinteisiä menetelmiä johtaessaan korjaushanketyömaita. Ongelma on, että käytetyt välineet ja menetelmät eivät aina kovin hyvin sovellu monimutkaisiin rakennushankkeisiin, joita erityisesti korjaushankkeet ovat. Lisäksi käytetyillä suunnittelu- ja johtamismenetelmillä ei ole kunnollista teoreettista perustaa. Tämän vuoksi on tunnistettu monenlaisia hävikkejä ja ylimääräisiä kustannuksia, kuten odotusaikoja, keskeytyksiä työmaalla, korjaustöitä jne. Tämä on johtanut tehottomaan toteutukseen, toisin sanoen heikkoon tuottavuuteen, viiveisiin ja kustannusylityksiin. Ensimmäinen askel kohti parempaa tuotannon johtamista korjaushankkeissa on tunnistaa hankkeiden kompleksisuus, jotta oikea lähestymistapa on löydettävissä tähän prosessiongelmaan. Lean-rakentamisprosessi on havaittu keinoksi hallita korjaushankkeiden kompleksisuutta ja epävarmuutta. Lean-johtamisfilosofia integroi täysin muutos-, virtaus- ja arvontuottonäkökulmat. Julkaisu perustuu sekä kirjallisuuskatsaukseen että tapaustutkimusten tuloksiin. Lean-menetelmiin perustuvat johtamiskäytännöt osoittavat hyviä tuloksia monimutkaisissa rakennushankkeissa. Kirjallisuudessa esitetyt tapaustutkimukset osoittavat lean-teorian käyttökelpoisuuden. Lisäksi tutkimukset osoittavat merkittävää kehittämispotentiaalia korjaushankkeiden johtamiseen. Joukko lean-menetelmiä, työkaluja ja tekniikoita on tunnistettu. Tämä julkaisu on käyttökelpoinen korjaustoimintaa harjoittaville yrityksille ja vuokratalojen omistajille korjaushankkeiden kehittämiseen lähtökohdaksi. Yhteistyötä rakennusteollisuuden ja tutkijoiden kesken tulisi jatkaa. Vaikka lean-periaatteiden käyttökelpoisuus monimutkaisissa projekteissa on osoitettu, jatkotyötä tarvitaan arviointiin, mitkä käytännöt soveltuvat erilaisiin hankkeisiin ja myös tunnistamaan käytännön mahdollisuuksia ja esteitä. Lisätutkimukset olisivat myös tarpeellisia, jota ymmärrettäisiin, kuinka paljon korjaushankkeiden tehokkuutta on mahdollista parantaa lean-periaatteiden avulla. Julkaisu tulisi nähdä yhtenä vaiheena kehityksessä kohden syventävää tutkimusta kestävän korjaustoiminnan kehittämiseksi lean-periaatteilla.
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