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# LEAN TOOLBOX APPROACH FOR EFFECTIVE PREPARATION OF HOUSING REFURBISHMENT PROJECTS USING CRITICAL SUCCESS FACTORS

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## ABSTRACT

Refurbishment projects notably for social housing are special kinds of project for many reasons, including inflexible existing stock, low available budgets, involvement of residents staying in their homes during construction. Lean tools could be helpful not only during construction, but also in the preparation of projects including requirements definition, budgeting, design, engineering and planning. The preparation phase also has typical peculiarities including political and social aspects, and is often time and cost consuming. Much lean research has focussed on improving the construction of new built and private sector projects. In contrast this paper aims to demonstrate the merits of lean tooling in the preparation phase of social housing refurbishments. The research reported examined lean tooling applications and their effects on project success in selected case studies of social housing refurbishments in the Netherlands. The research was a design-based action research shaping a preselected catalogue of tools i.e. lean toolbox. Next tools were selected together with practitioners, for application in the case projects. After those interventions interviews were held to registers effects on critical success factors in the projects. Most of the tool applications from the lean toolbox approach appeared to be effective in harnessing critical success factors in the projects.

## KEYWORDS

Action research, housing refurbishment, lean construction process, lean toolbox, project preparation.

## INTRODUCTION

Refurbishment of social rental property is a complex task because of the high variability and specific context and the requirements. The residents often live in their houses during the refurbishment. Therefore, the refurbishment process has to go fast without nuisance. Besides the refurbishment must be very cost efficient because of small social housing budgets. Often the real estate is old and has undergone previous not well documented renovations, by the social housing associations and residents themselves (Priemus 2008).

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In recent years Dutch construction firms implemented lean principles to cope with this complex task. But the focus was mainly on the construction phase. Besides there is the wish to improve the so called preparation phase including definition, design, engineering and planning to reduce overall process costs of refurbishment projects in the Dutch social housing sector (Vrijhoef et al. 2017). Particularly the desire for improvement by housing owners and clients is to meet the broader set of critical success factors of social housing (Vrijhoef et al. 2018). Whereas lean has been particularly aimed at new built and private sector projects. Refurbishment is different particularly in the preparation phase, notably in the case of social housing.

Previously Kemmer et al. (2013) have identified refurbishment includes different features in comparison to new built projects. They refer to many other authors pointing 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 1995, 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 residents in occupation (Quah 1992; Ho & 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).

In addition, social housing refurbishment requires extra capabilities involving residents and in some cases refurbishments take place while residents stay in their homes during refurbishment. This requires elegant techniques and capabilities to cope not just with the complexity and variability of refurbishment, but also the complexity and variability caused by the specific type of clients, working in their presence and intervening in their living environments.

Previous research has indicated the merits of lean techniques and process tools for housing refurbishment. Tools and techniques have been identified to be potentially useful to improve efficiency in managing social housing refurbishment projects (Kemmer et al. 2013). Further to the previous work, this paper particularly aims at lean process tooling in the preparation phase i.e. requirements definition, design, engineering and planning of refurbishment projects of social housing. The research approach is aimed at identifying the influence of tools on critical success factors and thus on project success.

# CRITICAL SUCCESS FACTORS IN CONSTRUCTION

## CRITICAL SUCCESS FACTORS IN GENERAL

In order to identify critical success factors of social housing refurbishment projects, success-related factors for construction projects were taken from a study by Chua et al. (2002). They distinguished success factors for construction projects according to the project objectives of budget, schedule, and quality. In their layered model, they presented 67 factors of influence divided into four main project aspects: Project characteristics, contractual arrangements, project participants and interactive processes.

However, Chua et al. (2002) did not distinguish factors for construction project types. Refurbishment projects and particularly social housing refurbishments are quite unique because of the context and requirements. The research reported particularly identified the critical success factors of social housing projects rather than the critical success factors of construction projects in general. For this purpose, the factors of Chua et al. (2002) have

been assessed using the Analytical Hierarchy Process methodology (Saaty 1980). A hierarchy of factors was identified based on relative importance of the factors.

### SELECTION OF CRITICAL SUCCESS FACTORS FOR THE RESEARCH

In order to select and operationalise the critical success factors for this research the input of experts was used to determine the set of factors most eminent for project success. Following the four categories of Chua et al. (2002): A. project characteristics, B. contractual arrangements, C. project participants and D. interactive processes (Table 1):

Table 1: Selection of critical success factors for the research

| Categories of analysis | Critical success factors to be |
|---|---|
| A. Project characteristics | Adequacy of funding |
| B. Contractual arrangements | Realistic obligations and clear objectives |
| | Risk identification and allocation |
| | Adequacy of plans and specifications |
| | Formal dispute resolution process |
| | Motivation and incentives |
| C. Project participants | Project manager competency |
| | Competency of proposed team (all participants) |
| | Top management support (all participants) |
| | Level of service (all participants) |
| | Track record (all participants) |
| | Team turnover rate (all participants) |
| D. interactive processes | Formal communication |
| | Informal communication |
| | Schedule updates |
| | Control meetings |
| | Work organization |

## LEAN TOOLS AND PRINCIPLES FOR SOCIAL HOUSING REFURBISHMENT

### PREVIOUS CATEGORISATIONS OF APPLICABLE LEAN TOOLS AND PRINCIPLES

This research is aimed at the preparation phase of social housing refurbishment projects. The preparation phase of projects including design and engineering of built objects resembles the process of product development. Hoppman et al. (2009) have provided an overview of eleven lean principles in product development: (1) Strong leadership, (2) Set-based Engineering, (3) Process standardization, (4) Specialist Career Path, (5) Product variety Management, (6) Workload levelling, (7) Supplier Integration, (8) Responsibility based planning and control, (9) Cross-project knowledge transfer, (10) Rapid Prototyping, simulation and testing, and (11) Simultaneous Engineering.

Based on a literature review, previously Kemmer et al. (2013) coined a selection of eleven lean related tools worth to investigate their usefulness for housing refurbishment: (1) Collaborative Design, (2) Target Value Design, (3) Production System Design, (4) Last Planner System, (5) Line of balance, (6) Visual Management, (7) Cellular Manufacturing, (8) Multiskilling, (9) Prefabrication and Standardisation, (10) Mass

customisation, and (11) Benchmarking. They concluded this list of tools and techniques should be tested by construction firms and housing associations in practice in order to identify the potential to improve efficiency of housing refurbishment projects.

### SELECTION OF LEAN TOOLS TO BE USED FOR THE ACTION RESEARCH

Based on the overviews above, and further study, for this research a selection of lean related tools had been made to be tested in case projects to assess their effect on critical success factors in the preparation of social housing refurbishments. The tools were discussed and further selected based on their expected capacities particularly in project preparations to: 1) jointly create realistic coordinated planning, 2) properly assess the risks, 3) control the budget, 4) make good recordings of progress, 5) suggest solutions for disputes, 6) increase resident involvement and participation.

Based on this, the selection of lean related tools to be applied to cases in the research were completed and subdivided in key categories of application (Table 2). Different than in the execution phase of projects, the categories specifically applied to aspects in the preparation of projects including design, client involvement, budgeting, team building, training and building up information. This exercise also served to form a first framework for planning interventions as part of the action research. Next this framework served as the first conceptual design of the envisaged lean toolbox, eventually containing the selection of tested lean tools based on the research:

Table 2: Selection of lean related tools for the research

| Categories of intervention | Lean tools selected for interventions in case projects |
|---|---|
| Design | Agile Design Management, Target Value Design, Integrated Design, Set based design, Lean led Design, Collaborative design or co-creation |
| Resident | Early end user Involvement, Customer journey |
| Budget | Target Costing, Value Engineering |
| Collaboration | Early Contractor Involvement, Scrum, Takt planning, Lean planning, Daily stand up, Toyota Kata, Continuous improvement with PDCA, Skills matrix, Cross training |
| Information and communication | Frontloading, First run study, Visual Management, BIM |

## RESEARCH APPROACH AND METHOD

This research was undertaken as a design-based action research (Andriessen 2007). In design research the researchers have the scientific ideal of creating prescriptive knowledge in order to improve professional practice. This prescriptive knowledge should contribute to practice in the form of general solutions for real world problems. Next the prescriptive knowledge should also contribute to theory by highlighting the generative mechanisms that make the solution concept work (Andriessen 2007).

The prescriptive knowledge of lean management concepts and tools was used to lead the interactive design-based action research actively involving participants in the case projects. The lean tools were discussed and applied as interventions in the case projects. The design-based action research approach followed six steps (Table 3).

Table 3: Operationalisation steps of the interactive action research approach

| Steps in the action research | Operationalization of the steps |
|---|---|
| Step 1: Formulating project success | Firms and practitioners in each case were asked what makes the particular case project a success. The project success was formulated based on this. |
| Step 2: Identifying factors that influence project success | Specific success factors for the project were identified that could influence the project and its success positively or negatively. |
| Step 3: drawing a causal loop diagram | The success factors were put together in a causal loop diagram. This supported the insight and analysis of the mutual causality among the factors and externalities. |
| Step 4: designing the case intervention by choosing specific lean tools | Interviews to assess the expected of selected lean tools from the lean toolbox. Simulating the tool in a serious game to shape the intervention applying the tool in the preparation phase of the project |
| Step 5: redrawing the causal diagram | Reassessing and redrawing the causal loop diagram based in new insights from the serious game in the causality and effects to be expected in the case project |
| Step 6: intervening in the case project and assessing the effects | Implementing the lean tools and assessing causal relations and effects in the preparation phased of the case project |

## INTERACTIVE INTERVENTION SIMULATION AND TOOL APPLICATION

The researchers shaped the research process together with the practitioners in the cases i.e., the personnel from the construction firms and housing associations involved in the case projects.

The interventions followed the sequence: 1) swimming lane planning and four fields mapping of the current preparation process, 2) selecting and shaping lean tools from an online toolbox and simulating and experiencing the effects of the application of the tools in the preparation process of the project, and 3) respondent interviews and observations.

### Swimming lane planning and four fields map

All cases of the research started with the formulation of a swimming lane planning and four fields map in order to be able to locate appropriate process steps to apply lean tools. This was done together with the firms and housing association involved to fully understand the preparation process and assess the potential implications of applying lean tools.

### Lean toolbox and serious game

Next, based on the conclusions of the swimming lanes and four field maps, practitioners from the firms and housing association per case, with the help of researchers, selected and shaped lean tools from an online prepared catalogue of lean tools (toolbox). The online toolbox then simulated the tools selected in a serious game to let the practitioners experience the expected effects of the application of the tools in the preparation process of their project.

### Interviews and observations

The game presented typical situations the practitioners could face in reality based on which they had to make choices and use tools. The choices made and the tools used per

situation played multiple times, provided insight into cause-effect relationships in situations and learn about the effects of tools solving problems. In this way the practitioners appreciated critical success factors and interventions to achieve project success. This process was observed by the researchers alongside taking interviews.

# CASES OVERVIEW

There were seven case projects that were part of the study (Table 4). All cases represented renovation projects, of which some were specifically aimed at energy efficiency improvements. The projects were characterised using four variables, indicating the types and levels of complexity which appeared to be influencing the preparation and construction phases of the projects:

1. Housing type: apartment blocks versus terraced houses. Different design complexity,
2. Project size: Small project <10, average sized 10-50, big projects >50. Different organisational complexity,
3. Occupation: residents present in their homes or not during the construction. Different organisational complexity.
4. Contracts: traditional, long term alliances (LT) such as supply chain collaboration for multiple projects, or one off alliances (OO) for single projects.

Table 4: Characteristics and variables of the 7 cases

| Cases | Housing type | Project size | Occupation | Contract type |
|---|---|---|---|---|
| 1 | Apartments | <10 | Occupied | Alliance LT |
| 2 | Apartments | >50 | Occupied | Alliance OO |
| 3 | Houses | >50 | Occupied | Alliance LT |
| 4 | Houses | <50 | Occupied | Traditional |
| 5 | Houses | <50 | Occupied | Alliance OO |
| 6 | Apartments | >50 | Not occupied | Traditional |
| 7 | Apartments | >50 | Occupied | Alliance OO |

## CASE DESCRIPTIONS

In all cases the time of study did not exactly fitted the project preparation phases of the case projects. In most cases the preparations phases lasted longer than the time frame of the study. Also in most cases the preparation phases had already started before the case study started. In few cases the preparation phase had not yet finished before the end of the case study. Nonetheless the researchers succeeded in studying large parts of the preparation phases and applying lean tools in the projects (Table 5). In a few cases the influence and effects of the application of the interventions and the lean tools had to be interpolated within the scope of the case study via interviews with practitioners involved.

Table 5: Descriptions and lean tools applied in the 7 cases

| Cases | Description | Lean tools applied |
|---|---|---|
| 1 | Century old apartments in a large city. The property is fragmented into separate buildings. In general, 4 storeys with attic. The project is phased per building. | Early Contractor Involvement, Early residents Involvement, Integrated Design, Collaborate Design, Frontloading, Scrum |
| 2 | Renovation of two 5-storey apartment blocks. Built in the late 1950s and early 1960s. The ground floor consists of storage rooms. The 4 storeys were 2 times 2 floor apartments (maisonette). | Early Contractor Involvement, Takt planning |
| 3 | Renovation of 90 ground-level homes. Some semi-detached and others are terraced houses. Property has become fragmented i.e. some owned by residents due to sales over recent years. | Early Contractor Involvement, Early residents involvement, Early inspections, Takt planning, PDCA |
| 4 | Two parallel renovation projects towards Net Zero Energy levels. High speed renovation organised per housing block every three weeks. | Cross training, Lean planning, Daily stand up, Continuous improvement with PDCA, Toyota kata |
| 5 | General renovation including construction firm, roof specialist and an HVAC company. | Skills matrix, Cross training, Customer journey, Early resident involvement, Continuous improvement, Toyota kata |
| 6 | Renovation of 200 homes. Residents stood up for their interests. Therefore the housing association chose to coordinate the preparation themselves. Involve the main contractor in a late stage. | Early residents Involvement, First run study prototyping a trial refurbishment in a first home, lean planning |
| 7 | Renovation of 168 apartments, three storeys high. | Early residents Involvement, First run study, Lean planning |

### RESPONDENTS INTERVIEWS AFTER INTERVENTION

Finally, the practitioners were interviewed particularly relating the intervention and lean tool application to the effect on the critical success factors, as identified earlier. Respondents were asked whether the factor had a positive or negative influence on the project success, actually or expectedly, depending on the phase of the project. In particular, the performance of the lean tools selected in the simulation versus the performance during the intervention were discussed. And expert opinions were asked to clarify differences between both levels of performance. In the case analysis below causal diagrams were drawn based on the relations found, and validated by the practitioners involved.

## CASE RESULTS

The interventions and lean tool applications in the cases indicated success factors being both generic project characteristics and also contextual peculiarities of social housing refurbishment. All cases referred to economic risks and adequacy of funding. Particularly in social housing budgets are very limited. Building up time pressure was also seen as a critical project characteristic and a problem in preparations of refurbishment projects in

social housing. Particularly due to specific regulatory, social and financial requirements delays resulted in long lead times of early projects phases that could take years.

As a result, contractual arrangements were seen as problems in relation to unclear definitions of realistic obligations and objectives. Social housing associations were found trying to cope with this factor by involving the contractor in an early stage of the definition and planning phase i.e. early contractor involvement.

In most of the cases the commitment and authority by the project management was found critical. But also the competences and flexibility of the project members were critical success factors to cope with unexpected events of different kinds in social housing refurbishments. Team members had to experience authority and at the same time be able to influence processes and propose solutions based on their expertise. On site and in homes personnel needed to be skilful in formal and informal communication with residents, particularly while residents have the right to disagree with the refurbishment.

Another critical success factor was the competence of the client, the social housing association, and the consultants of the client. Skilfulness and capabilities of the client's project manager proved to be a very critical factor of success.

## WITHIN CASE ANALYSIS

In some cases, the different success related factors interacted with each other in a complex way. As a result, multiple causal loops existed in the case findings per project. In figure 1 the example of one case shows multiple causal relations between adequacy of funding, budget updates, capabilities of personnel, level of automation and realistic obligations and clear objectives. Those relations caused three interacting causal loops: 1) a budget loop, 2) a project team loop and 3) a schedule loop.

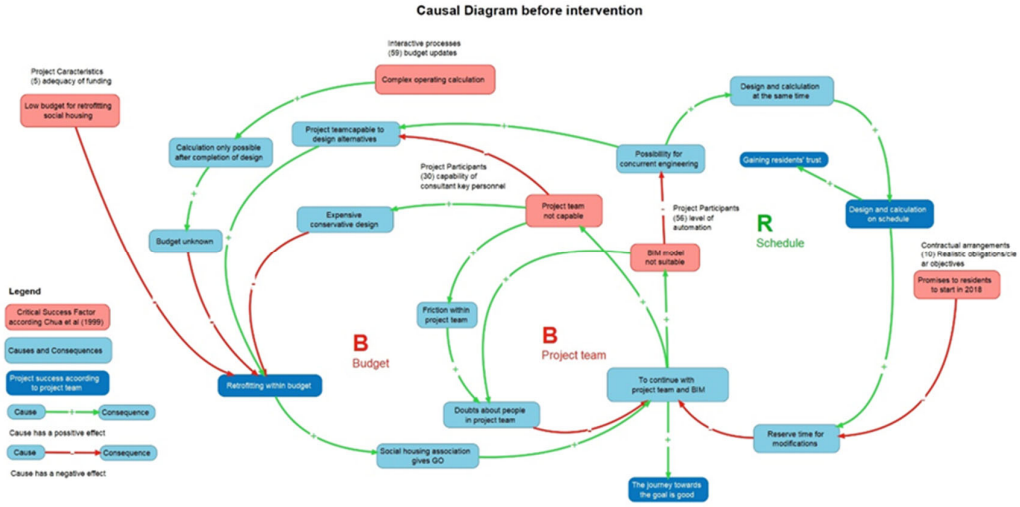


Figure 1: Causal diagram of one of the cases including three causal loops

The budget loop appeared to be a balancing loop (B). The reason was the project team used a Building Information Model (BIM), but the model did not give enough insights. The consequences were that the project team was not able to design a less expensive alternative solution and instead produced a more expensive design. The design was well above the maximum available budget. However, the exact budget was unknown because the exact budget could only be calculated when the design was completely ready.

The project team loop was also a balancing loop (B) as a result of misunderstanding in the project team. Misunderstanding arose from persistent misinterpretations of the BIM model. This caused continuing doubts and mistrust among the project team members from the firms, and strengthened the idea of housing association to change the project team.

The schedule loop however was a reinforcing loop (R). The BIM model gave too little information for the cost calculations during the design. The calculation was done after the design was completed. Both the design and calculation were not on schedule and there was no buffer time left. The solution of replacing the project team would cause extra delay and unaffordable financial claims. So the project team could not be changed and the schedule kept overrunning.

These complex causal multiple loops existed in most cases, and were particularly found to be troublesome to unravel and frustrated the project teams.

## CROSS CASE ANALYSIS

Next a cross case analysis was performed by using the Context Mapping Method (Stappers 2012; Visser et al. 2005). In the cross case analysis learnings from project teams involved were categorized and matched to the previously selected critical success factors by Chua et al. (2002). The result of the cross case analysis was an inventory of critical success factors and their translation in terms of how they emerged in the preparation phases of the social refurbishment cases studied. Different notions and experiences of project success were reformulated and restructured into a common set of critical success factors. The following critical factors for project success emerged across the cases:

- Time availability
- Project management involvement
- Project management capabilities
- Capacities of the project team
- Authority and expertise of project team members
- Economic risks
- Clear goals and expectations
- Doing inspections and recordings of work
- Formal and informal communication with residents.

More specifically from the perspective of social housing refurbishment projects, across the cases the following effective combinations between lean tool applications and principles (following the lean principles by Hoppmann et al. 2009) on the one hand, and their effect on critical success factors that have emerged in the case studies on the other (following the preselected critical success factors by Chua et al. 2002) (Table 6):

Table 6: Critical success factors connected to lean tools, and their manifestation in cases of social housing refurbishment projects

| Critical success factors | Manifestation of success factors in cases | Connected lean principle | Manifestation of lean tools in cases |
|---|---|---|---|
| Adequacy of funding | Sufficient budget with room for plausible deviation. | Rapid prototyping, simulation and testing | First run studies make work transparent and reveal potential hidden issues in existing stock. |

| | | | |
|---|---|---|---|
| Realistic obligations and clear objectives | Realistic planning based on firm pre-analysis of projects. Clear view on client's and residents' expectations. Firms share same aim. | Responsibility for planning and control | Joint planning verified by all to prevent 'planning optimism'. Inserting strategic buffers without making deviations easy. |
| Risk identification and allocation | Clear risks and good assessment of potential setbacks. Being able to absorb variations and unexpected events. | Product variety Management | Proposed solutions possess minimally needed levels of flexibility capable to cope with variation. |
| Adequacy of plans and specifications | Realistic planning and design based on firm pre-analysis of projects and discussion. | Set-based engineering | Offering multiple flexible alternatives based on expertise of suppliers. |
| Formal dispute resolution process | Agreed upon procedures for joint decision making. | n/a | n/a |
| Motivation and incentives | Joint understanding of client expectations and rewards, financial and non-financial. | n/a | n/a |
| Project manager competency | Presence of strong project management demonstrating leadership from start to end. | n/a | n/a |
| Competency of proposed team (all participants) | Sufficient team members experienced in type of project. Knowledge transfer to other team members. | n/a | n/a |
| Top management support (all participants) | Involvement of management of housing association; articulated client value to be delivered to residents | Cross-project knowledge transfer | Formal and informal learning across projects supported by long term alliances and commitment. |
| Level of service (all participants) | Clear specification of solutions and products. | n/a | n/a |
| Team turnover rate (all participants) | Clear expectations to the team. Reserve staff able to take over in case of turnover. | Specialist Career Path | Being able to exchange multi-skilled personnel between tasks. |
| Track record (all participants) | Knowing partners' expertise and strength based on previous joint experience. | Supplier integration | Involving known suppliers in an early stage in the design and engineering |
| Formal and informal communication | Clear communication structure. Extensive discussion in preparation. | n/a/ | n/a |
| Schedule updates | Joint planning and high level of detail in lean planning | Workload levelling | Frequent checks and updates of planning. Redistributing work time among suppliers. |
| Control meetings | Frequent meetings lead by strong project manager. | Simultaneous engineering | Early involvement suppliers in design and meetings with residents for expectations. |
| Work organization | Explicit formulation of responsibilities and fostering knowledge exchange in team. | Process standardization | Formalising process control independent from personal preferences of individuals. |

# DISCUSSION

The research reported has ascertained various patterns and expectations with regard to categorisations, usefulness and interconnections of and between critical success factors and applicable lean tools in construction projects and notably social housing refurbishments.

However, findings also showed inconsistencies between existing studies on the one hand, and views and evidence found in the case studies, indicating contradictions between theory and practice. The understanding and value attributed to lean tools and the explanation of success differs between theory and practice. The effect and value of lean tools is generally found less powerful in practice than expected based in theory, for instance regarding budget control and resident involvement. Based on theory the expectations were larger than the empirical evidence in this research actually showed.

The research also indicted that more power and performance have been granted to lean tools in the simulation game than afterwards during the actual intervention in the reality of the case projects. Particularly due to increasing insight and complicating effects from external factors and non-conformance of residents as non-professionals to professional expectations of applying lean tools and understanding of construction projects as professional contexts.

# CONCLUSION

In the cases the selected critical success factors from Chua et al. (2002) were found, and in most cases a connection or causal effect existed with the lean tools applied from the lean toolbox that was devised for this research. Generic problems of construction as well as specific problems of social housing refurbishment appeared and in most cases could be solved or alleviated with lean tools. Some lean tools stemming from new built context were customised for this purpose. Even so some problems formed a causal loop or were so specific for social refurbishment that they were hard to solve with the lean tools.

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