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IMPLEMENTING LAST PLANNER IN THE CONTEXT OF SOCIAL HOUSING RETROFIT

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ABSTRACT

The paper aims to investigate the implementation issues and benefits of utilising the Last Planner and 4D modelling in the context of retrofit of social housing. It presents initial results of an on-going research project carried out in Northern Ireland, which focuses on the retrofit of solid wall homes. The research project involves the proposal of a process in which BIM is used to evaluate what-if scenarios for the retrofit of social housing with a focus on reducing user's disruption throughout the construction process. Both 4D and the Last Planner are used to ensure the retrofit works with the minimum disruption.

A case study on the retrofit of a set of houses was carried out, which is part of a bigger research project entitled S-IMPLER. Data was collected via semi-structured interviews, participant observation in planning meetings, site visits and documental analysis. The study sheds light on a particular type of project that has not been well explored by the lean community, i.e. retrofits. It is argued that the results can be applicable to support the retrofit of a number of solid wall homes throughout the UK.

KEYWORDS

Retrofit, disruptions, production, last planner system.

INTRODUCTION

Retrofits, or sustainable retrofits, refer to the refurbishment of buildings with the purpose to improve their energy performance (Swan & Brow 2013). This type of refurbishment has been gaining importance within the construction sector as it plays a vital role in the achievement of sustainable targets (Kelly 2009).

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The retrofit process presents many challenges for managers and decision makers, particularly when the users remain in the building over the period that the works are carried out (CIRIA, 2004). The retrofit works cause disruptions for building users, which need to be treated as an additional variable in managing retrofits and considered as part of the strategic objectives in such projects (Kelsey 2003).

This scenario offers an interesting opportunity to investigate the applicability of lean principles in order to tackle the issues inherent to retrofit projects. Despite being well tested in new build projects, the implementation of lean methods in retrofits has been scarce (Kemmer & Koskela 2012). This study contributes to fill this void by exploring the potential of using Last Planner System (Ballard 2000) with the support of Building Information Modelling (BIM) to ensure the retrofit works with the minimum disruption.

LEAN IN RETROFIT PROJECTS

There are around 4.95 million of dwellings in the UK's social housing stock (DCLG 2015). A significant part of these homes do not meet the minimum requisites of insulation and energy conservation and, therefore, require retrofit activities to improve the thermal comfort and to replace building components at the end of its useful life (Itard et al. 2008). The problem is that the majority of those homes are owner-occupied which enhance the difficulty of retrofit works and the possibility of users' disruptions. Lean principles might be an interesting option to tackle the issues inherent to retrofit projects.

Several authors have highlighted the need and opportunity for investigating the applicability of lean principles in retrofit projects (Smith & Owen 2011; Brayshaw et al. 2012; Swan 2013). However, there is still limited evidence of practical applications of the lean theory in the refurbishment sector as a whole, including retrofits, especially when compared to what is found regarding new builds (Kemmer & Koskela 2012).

Despite the lack of research on the application of lean in retrofit projects, it is worth mentioning that there are few examples available in the literature demonstrating the usefulness of lean initiatives in such projects. For example, Tuholski and Tommelein (2008) and Tuholski et al. (2009) show the potential of lean tools such as design structure matrix methodology and cross-functional process charts for optimizing the design process on complex seismic retrofit projects. Ladhad and Parrish (2013) contend that lean practices such as learning from previous projects, shared understanding, early integration of design and construction teams are also useful for promoting energy savings during the building's lifecycle. Last Planner System (Ballard 2000), the well-known lean method of production planning and control, is also mentioned as a useful tool for improving coordination and integration among project participants (Ladhad & Parrish 2013).

Although providing inspiring results, those studies have not addressed the context of social housing retrofit. It is argued that such project context has particular characteristics and management challenges that might demand specific lean approaches. This study contributes to the existing literature by discussing the implementation issues and potential benefits of applying Last Planner with the support of BIM in a social housing retrofit.

BIM IN RETROFIT PROJECTS

According to Hammond et al. (2014), BIM has potential to be used in retrofits in the following areas: (a) determine the level of green building certification systems can be achieved (e.g. LEED); (b) perform building analyses, such as, orientation, massing, envelope, daylight to enhance design; (c) perform analyses on building functions, as energy and water use, ventilation and lighting. In addition, BIM model created for retrofit works can be also used in a cost estimating software to calculate the cost of retrofit and in others software for further building maintenance and operation (Ilter & Ergen, 2015).

Despite the potential of BIM for retrofit projects, there are no studies about its use to analyse end user's disruption. Therefore, this study is focused on filling the gap about the benefits and challenges in use BIM tools to reduce the user's disruptions, as it is a common problem faced in retrofit works.

THE S-IMPLER PROJECT

The work presented in this paper is part of a wider research project entitled Solid Wall Innovative Insulation and Monitoring Processes using Lean Energy Efficient Retrofit (S-IMPLER), funded by the Innovate UK (http://www.s-impler.com). This project aims to develop a retrofit solution for social housing, which were built with solid walls, to achieve 60% reduction in monitored energy costs, at least 10% faster than conventional installations, with less disruption for end users, without reductions in quality and safety.

This research initiative involves a housing association, two academic institutions, an independent research organisation, an energy service supplier, a building contractor, a consultant on continuous improvement, an architectural practice, a company specialised on energy management solutions, a software company, and material suppliers. The application of lean and BIM practices are part of the elements investigated in the project. The retrofit work consists of:

- Replacing the old external windows and doors made of wood and single glass by openings made of PVC and double glass;
- Strengthening of the existing loft insulation layer;
- Insulation of external walls using insulation dynamic boards and rendering;
- Switching the existing oil boiler with natural gas boiler heating system;
- Switching the ventilation system with a more efficient one.

The retrofit work will be carried out in five different phases to enable analysis, learning and improvements between phases. This paper specifically reports on the use of Last Planner and 4D modelling with the purpose to reduce user's disruptions.

RESEARCH METHOD

A case study was carried out to evaluate the implementation issues and benefits of utilising the Last Planner System and 4D BIM modelling in the retrofit of a set of houses. This study is part of an on-going research project conducted in Northern Ireland, which involves the refurbishment of eight houses in five phases (see details below). This paper reports findings from the first three phases (Table 1). The objectives set for each phase along with the methods used in this investigation is presented in the following table.

Table 1: Research process.

Items	Phase 1A	Phase 1B	Phase 2
Objectives	(a) understanding of project's current status, (b) problem identification along with root cause analysis, (c) identification of opportunities for improvement	(a) introduction of Last Planner with the support of 4D BIM modelling, (b) identification of opportunities for improvement	(a) use of BIM for what-if scenarios simulations and use of line of balance for assessing disruptions, (b) identification of opportunities for improvement
Research methods	Semi-structure interviews, direct observation of works on site, documental analysis	Participant-observation in planning meetings, direct observation of works on site, documental analysis	Participant-observation in planning meeting, documental analysis

As illustrated in the table above, the first phase of the study was exploratory. In order to achieve the goals set for this initial stage, it was conducted semi-structured interviews with project participants (e.g. project manager, site manager, consultant, architect, etc.), direct observation of works on site, participant observation in planning meetings, and documental analysis (e.g. production plans, scope of works, design drawings). As the main goal of this phase was just to understand the current planning system, the researchers made no intervention in the process of production planning and control.

In the phase's 1B and 2 the researchers collaborated closely with project participants. This refers to a pro-active participation in the implementation of Last Planner and 4D BIM modelling, i.e. facilitating planning meetings, devising plan options, making direct observations on site, and analysing documents related to production planning and control.

RESEARCH FINDINGS

PHASE 1A – EXISTING PRODUCTION PLANNING AND CONTROL SYSTEM

The first phase of the project involved the retrofit of one house, which was void during the construction. The team assembled for the delivery phase was led by a project manager who was responsible for managing a group of material's suppliers, an architect responsible for the retrofit design, and the subcontractor assigned for carrying out the works on site. Such team will be referred in this paper as "the delivery team".

In order to get ready for the retrofit, the delivery team met four weeks prior works were due to start on site. The main goals of this meeting were to devise the construction programme and phase sequencing as well as checking the prerequisites for the retrofits such as design information, material and labour supply. Such tasks were facilitated by the project consultant and performed by the delivery team in a collaborative fashion through the use of post-its notes for setting deadlines for removing the project's constraints and milestones for the main construction processes. Four weeks later the retrofit began as planned. The lead time planned for the retrofit in this phase was four weeks.

During the construction phase, the production planning and control process was carried out in an informal basis. There was no formalisation of plans, apart from the construction programme generated at the outset. Such plan, which served as a master plan for this first phase, become out-dated quickly as the sequence of works agreed initially changed during construction. Likewise, the problems on site were not systematically registered since there was no formal document for that purpose.

Several problems were identified during the construction phase such as disruptions in the workflow (main problem), downtime, and rework. The lack of materials (e.g. windows and insulation components) and design information (e.g. detailed drawings) caused such problems. However, the analysis of the root causes, carried out by the delivery team during an improvement meeting after the completion of the retrofit, revealed that such problems were mostly due to inefficient communication amongst the team, as neither the communication structure within the project nor the roles and responsibilities of each participant were clear, and also due to the compressed time for developing the design, which resulted in the lack of information for carrying out the works on site as planned. The actual lead time for retrofitting the house was eleven weeks.

In terms of opportunities for improvement, the delivery team decided that no works on site should get started until all uncertainties were resolved. This decision was made in order to prevent disruptions in the workflow and downtime, therefore enabling the compression of the lead time for the next retrofit phase. Also, a web-based project management platform was set up and a meeting was organised by the project consultant in order to streamline the communication and foster collaboration amongst the team. Besides, it was decided that a formal production planning and control approach should be adopted so better results could be achieved (e.g. less disruptions, compressed lead time).

PHASE 1B – INTRODUCTION OF LAST PLANNER AND 4D BIM MODELLING

The second phase of the project involved the retrofit of two houses, both occupied during the construction. In order to produce a predictable workflow and rapid learning as well as reducing disruptions on site, the Last Planner System (LPS) of production control was adopted. 4D BIM modelling simulations were also used as a visual aid to support decision-making within the LPS framework. They aimed at contributing to the development of the master plan by showing the implications of different production strategies in terms of disruptions for the residents. The target lead time set for this second phase of the project was four weeks for the retrofit of both houses.

In order to implement the LPS in such specific project context, some adaptations had to be made. These are summarised in the following table.

Table 2: Last Planner's adaptations to suit the retrofit context.

LPS elements	Phase 1B
Long-term (master plan) Phase planning	Devised in a collaborative fashion by the delivery team through the use of post-it notes and a location-based chart
Medium-term (lookahead plan)	Constraints were listed for the entire project duration
Short-term (commitment plan)	Devised on a daily basis to register the assignment of tasks to crews on site
Learning	Daily measurements of Percent of Plan Complete (PPC) along with root cause analysis

As illustrated in the table above, the master plan and phase planning were devised simultaneously due to the characteristics of the project, namely, a retrofit of small houses planned to be executed in short amount of time. In this paper, such plan will be referred as "master plan". It was devised by the delivery team through the use of post-it notes fixed on a chart at the site office as showed in the following figure.

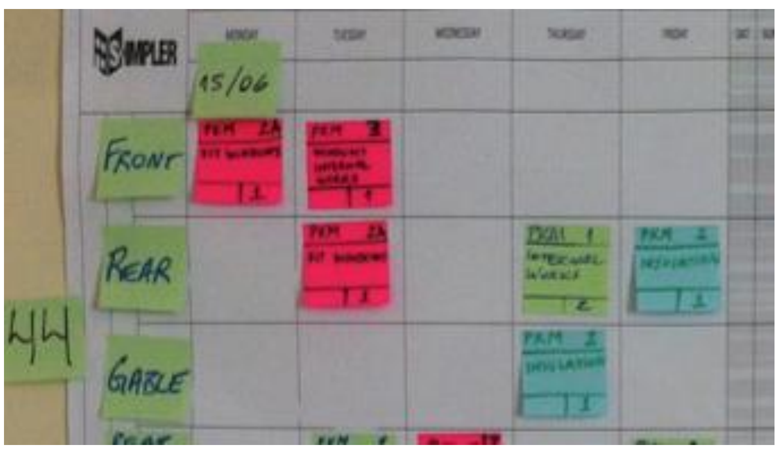


Figure 1: Post-it notes fixed on a location-based chart at the site office (master plan).

The number 44 in Figure 1 represents the house number and the locations (e.g. front, rear) refer to the facades of the house. The selection of facades as programming batches is due to the main retrofit processes (e.g. windows and doors, external wall insulation, and rendering) being executed in such areas. The different post-it colours indicate distinct retrofit processes. The post-it information was standardised and included the crew size, the task and its duration.

The lookahead planning was carried out for the entire project duration, i.e. four weeks. A list of constraints was generated and circulated via the web-based platform in order to communicate the deadlines and necessary actions to the delivery team. The short-term plan was carried out on a daily basis as well as the PPC measurements and root cause analysis. The actual lead time for retrofitting both houses was 6 weeks.

In terms of problems, there were still disruptions in the workflow due to the lack of materials. However, the root cause analysis indicated that the problem was actually linked to a failure in checking the quantity of material available for carrying out the insulation works. It is worth mentioning that such disruptions were considered as a minor problem and not a major issue as noted in phase 1A. Another problem faced was the lack of subcontractor's collaboration in the planning meetings as the foreman showed resistance to formalise the plans as well as analysing the problems and their root causes.

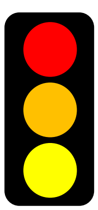
In terms of improvements, it was realized that the 4D BIM simulations were too detailed to enable the visualisation of the sequence of activities with clarity. As a result, it was agreed that the models should be redeveloped with a lower level of detail. Furthermore, collaboration was deemed as critical for the success of the next phases of the project so a meeting was organised with a representative from the subcontractor in order to tackle that issue.

PHASE 2 – WHAT-IF SCENARIO SIMULATIONS TO EVALUATE DISRUPTIONS

Phase 2 comprises the retrofit of two houses, both occupied during the construction. 4D BIM models were used in this phase as a means to evaluate what-if scenarios for the retrofit with a focus on reducing user's disruptions throughout the construction process.

This phase started with the definition of production scenarios and their activities sequence and work packages. For each scenario, different capacities of production resources were used, which caused different durations for the retrofit works. Also, three lines of balance were developed to enable the analysis of the number of disruption days in each house and the number of planned workers. This analysis was done on the basis of a classification of the work packages that could cause more disruptions for the end users (Table 3). The lead time planned for the retrofit in this phase was four weeks.

Table 3: Levels of disruptions of work packages.

Disruption level		Work packages
		Windows, External door, Internal Works, Loft insulation, Building services
		Lobby, Render, Facades elements
		Mobilisation, External Wall Insulation, Eaves, Demobilisation

The most disruptive activities for users, classed in red in the table above, are the ones that cause interruption of everyday life due to the need to access the houses inside and/or suspend the provision of building services. This information was essential to adjust the line of balance in order to reduce the number of overall disruptive days. Each period in which the disruptive activities (red and orange categories) took place in the house was counted. The parameters for each production scenario created for phase 2 are described in Table 4.

Table 4: Production scenarios developed for phase 2.

Scenarios	House number	Total duration (days)	Period disruptions Red (days)	Period disruptions Orange (days)	Total disruptions / house (days)	Total disruptions / scenario (days)	Total workers
Scenario 1	46	19	6	16	22	41	9
	47	20	7	12	19		
Scenario 2	46	21	9	14	23	41	7
	47	21	8	10	18		
Scenario 3	46	21	7	15	22	42	8
	47	22	7	13	20		

Scenario 1 is considered as the best option since it presents the shorter duration and less disruptive days than the other scenario. However, an evaluation of this result is needed with the project team, as this option requires more workers. This evaluation is planned to happen in the near future as the project is still on going.

DISCUSSION

The compression of the lead time noted between phase 1A (11 weeks) and phase 1B (6 weeks) can be seen as a benefit of utilising the Last Planner System (LPS). Principles associated to the LPS such as focusing on removing constraints before starting works on site and learning from mistakes were certainly factors that contributed to reduce disruptions in the workflow as well as compressing the retrofit lead time. The learning effect, evidently, cannot be ruled out as an additional cause of such improvements.

Another benefit of using LPS is the improvement in the project coordination and communication. For instance, the formalisation of the list of constraints fostered the interaction amongst project participants and assisted the project manager in coordinating the issues required for enabling the start of works on site. Also, it created a baseline of potential issues that can be used from phase to phase to avoid unnecessary disruptions in the workflow.

In terms of the LPS implementation issues, two aspects deserve attention. First, there was a need to promote adaptations in the way the LPS basic elements were applied in order to suit the retrofit context (Table 2). As the project referred to a retrofit of small houses to be executed within a short amount of time, it was decided to list constraints for the entire retrofit duration so uncertainties could be anticipated and disruptions avoided, besides daily, not weekly, plans were put in place in order to enable the creation of basic stability and establishment of short learning cycles. Also, the use of a visual management tools such as the location-based chart along with post-it notes for displaying the master plan helped to improve the understanding of project participants regarding the production strategies. Second, poor collaboration was considered as a major issue faced during the study as it precluded the appropriate formalisation of daily production plans and, as a result, it impeded the evaluation of daily production performance as planned. Such issue, addressed during phase 2, highlights the need of gaining top management support prior the implementation of LPS on site.

Regarding the use of 4D BIM simulations as a visual aid during the development of the master plan, an important lesson was learned, namely, the 4D model must correspond to the level of detail of the plan analysed. The use of a detailed model in phase 1B did not produce the expected results since the participants could not see clearly the sequence of activities as well as the potential disruptions associated to each production scenario.

Another important finding was the need of combining different tools to enable a better assessment of disruptions. The 4D BIM models should be used along with the Line of Balance (LOB) since the latter is better in analysing the disruptions according to the categorization devised in the study. The identification and counting of number of disruptions in the LOB proved to be easier than what was found when using the 4D BIM models. In fact, without the LOB, the creation of what-if scenarios as presented in Table 4 would not have been possible. The 4D BIM models are helpful for communicating the construction programme to clients and also valuable to enable the visualisation of aspects related to site logistics such as material storage, scaffolding position, and users' access.

CONCLUSIONS

The aim of the paper is to discuss the implementation issues and benefits of utilising Last Planner with the support of BIM 4D modelling in the context of retrofit of social housing. It focuses on reducing user's disruption throughout the construction process.

Regarding the benefits of utilising Last Planner, the research findings indicated that there is a potential, especially with regards to reducing the disruptions on site and compressing retrofit lead time. Improvements in project communication and coordination were also noted as a result of the LPS adoption. In terms of implementation issues, the need for adapting the basic elements of LPS in order to suit the retrofit context as well as getting buy-in from top management staff prior to start works on site were deemed as vital factors towards a successful practical application.

The use of 4D BIM simulations was also assessed during the development of the master plan as a supporting tool for stressing potential disruptions resulting from distinct retrofit strategies. The main finding on this matter is that the assessment of disruptions in such projects should consider the use of additional tools, e.g. the line of balance method, as the 4D BIM models are incapable to provide information about disruption in a suitable way, i.e. they do not allow comparison of scenarios as easy as the line of balance does.

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