DEVELOPMENT OF A METHOD FOR CONSTRUCTION MANAGEMENT IN REFURBISHMENT PROJECTS

SERGIO KEMMER

A thesis submitted to the University of Huddersfield in partial fulfilment of the requirements for the degree of Doctor of Philosophy

The University of Huddersfield

April 2018

Abstract

Refurbishments have different features in comparison with new build projects. This refers mainly to the fact that they are carried out in an existing asset that might remain in operation. Such characteristics increase the complexity inherent to construction settings. Yet, studies indicate that mainstream practices, that are not capable of dealing with complex projects, are predominantly used for managing production. Prior research suggests that the use of such an incompatible management approach is likely to lead to poor performance. Indeed, problems in managing refurbishments have been identified in several countries.

Despite this troubling scenario, the management of refurbishment works has not been properly addressed in the current research agenda. There are numerous studies related to the broad refurbishment area, but only a small number refer to the way those projects are managed. Moreover, the majority of studies about this topic have not been based on a proper theory of production. Clearly, there is a gap in this research domain.

In order to fill such a gap, this research aims to developing a method for construction management in refurbishment projects, with the purpose of improving production performance, by indicating appropriate approaches of production control. The method comprises a conceptual model of refurbishments, a framework for project characterisation, and a list of managerial solutions, grounded on a robust theory of production and suited to the context of refurbishments.

The constructive research approach is adopted in the study. Two rounds of empirical studies were conducted throughout the research. Firstly, two studies were carried out to obtain a deeper understanding of the topic investigated and to develop the initial version of the method. Secondly, a study was conducted to implement and refine the artefact. Thirdly, a focus group was organised to evaluate the utility of the method, to refine it, and to examine its scope of applicability.

The main theoretical contributions of the study, embrace the conceptual model of refurbishments to support effective construction management, the framework having project dimensions for helping managers to cope with the management of complexity innate to refurbishments, and the framework of managerial solutions for production management. In practical terms, the study showed that the application of the method assisted managers in choosing suitable practices for managing construction in a retrofit project and contributed to enhance project performance. Moreover, it is contended that the method can be used to help organisations to get started on lean in refurbishment projects.

Table of Contents

List of Figures

List of Tables

Dedications and Acknowledgements

Many people and organisations contributed to this investigation. First of all, I would like to thank Mr. Veijo Nykänen from VTT Technical Research Centre of Finland and the funders of ApRemodel Project for the possibility of working with lean refurbishment. This project was the motivation for developing this research. Many ideas conveyed in this thesis sprung from the research developed in the ApRemodel Project.

Equally important for the development of this thesis was the support I received from the National Council for Scientific and Technological Development (CNPq) in Brazil. This study would not have been possible without the scholarship provided by the CNPq.

I am grateful to my supervisor, Professor Lauri Koskela, for his support and wise guidance throughout the research. I could not have done this work without his valuable criticism and serenity. I am also thankful to Professor Arto Kiviniemi for the useful discussions we had at the early stages of the study when he was my co-supervisor at the University of Salford.

Special thanks to my dear friend Ricardo Codinhoto for all the help since the moment I decided to pursue the PhD. He looked after my wife and myself in every way possible. I am also thankful to Cecilia Rocha, Diego Souza, and Danilo Gomes for the friendship and rich discussions we had on this research as well as the invaluable insights and comments.

I would like also to express my appreciation to the companies and to all the professionals that contributed to this investigation. In particular, I want to thank James McMillan for supporting the empirical study in England, Flavia Rodrigues de Souza and Renato Kaufmann for helping with the study in Brazil, Sigmund Aslesen and Roar Fosse for the assistance in Norway, and the participants of the S-IMPLER Project in Northern Ireland for kindly taking the time to contribute to this research.

There are also many people who had an influence on this research. Professor Ercilia Hirota and Professor Luiz Heineck for instilling the passion for research on me. Professor Thais Alves and Professor Carlos Formoso for the incentive in pursuing the PhD. My colleagues from the University of Salford, Karen West, Algan Tezel, Bhargav Dave, Carl Abbott, Will Swan, Martin Cleary, Ergo Pikas, Stelios Sapountzis, John Rooke, Clementinah Rooke, Bob Owen, and also from the University of Huddersfield, Saeed Talebi, Clarissa Biotto, Sophie Phillips, and Sharon Baines. My sincere thanks also to the members of the panel of the IGLC Summer School in 2013 for the relevant contributions they made to the development of this report. In particular, I would like to mention Professor Iris Tommelein and Professor Greg Howell for the discussions during the IGLC's conferences.

I cannot forget to recognise the precious support I received from my friends. To name a few: Claire McGuire, Monika Rihova, Pei Shan, Guilherme Biesek, Sahar Karimi, Lisiane Lima, Tomas Cajueiro, Fico de Cárdenas, Natalia Vidalón, Fernanda Chaves, Luciana Miron, Tarcisio Saurin, Carles Ruiz de Apodaca, Gemma Fabregat, Talita Gandara, Leonardo Delai, Blanca Araujo, Javi Senz, Manuela Fazzan, Guilherme Fazzan, Lia Nardin, Bruno Mota, and many others that made this period an enjoyable and unforgettable life experience.

I would like also to express my deepest gratitude to my family for the unconditional support, especially my parents Luiz Carlos and Nereide, and my brothers Rafael and Luiz.

Finally, I would like to thank the most important person in this process, my wife Vanessa for all her love and support during this effort, for blessing us with our lovely daughter Luiza, and for putting up with me, especially my absences from home.

Huddersfield, April 2018.

Sergio Kemmer

List of abbreviations

BRI - Building Research & Information

CE – Constructing Excellence

CII – Construction Industry Institute

CIRIA - Construction Industry Research and Information Association

CPM – Critical Path Method

DCLG – Department for Communities and Local Government

DECC - Department of Energy & Climate Change

FEP – Front End Planning

HMT – Housing Management Team

HSE – Health & Safety Executive

IGLC – International Group for Lean Construction

JPF – Joao Pinheiro Foundation

LCI – Lean Construction Institute

LOB – Line of Balance

LPS – Last Planner System

M&E – Mechanical and Electrical

MEP – Mechanical, Electrical, and Plumbing

MRP – Material Requirements Planning

NBS – National Building Specification

NCE – New Civil Engineer

ONS – Office for National Statistics

PDRI – Project Definition Rating Index

PERT – Programme Evaluation and Review Technique

PPC – Percent Plan Completed

PSD – Production System Design

RLO – Resident Liaison Officer

TFV – Transformation-Flow-Value

TLO – Tenant Liaison Officer

TSB – Technology Strategy Board

VM – Visual Management

WWP – Weekly Work Plan

Publications

This dissertation shares part of its contents with the following publications:

Kemmer, S., & Koskela, L. (2012). Developing a lean model for production management of refurbishment projects. In *Proceedings of the 20th Annual Conference of the International Group for Lean Construction*, 17 July to 22 July, San Diego, USA.

Kemmer, S. & Koskela, L. (2014). Understanding production management of refurbishment projects of a housing association – an exploratory case study. In *Proceedings of the 22nd Annual Conference of the International Group for Lean Construction*, 23 June to 27 June, Oslo, Norway.

Kemmer, S., Biotto, C., Koskela, L., & Fazenda, P.T. (2016). Implementing Last Planner in the context of social housing retrofit. In *Proceedings of the 24th Annual Conference of the International Group for Lean Construction*, 18 July to 24 July, Boston, MA, USA.

Chapter 1 Introduction

This chapter presents the subject addressed in this investigation. Firstly, the importance of refurbishment projects is broadly described. Secondly, an overview of the research available on the topic examined is presented. The research problem confronted by the study is defined in the third section. The fourth section states the aim of study, along with the questions that guided this investigation. The fifth section introduces the research method utilised by the author, and section six sets the focus and scope of the study. Finally, the seventh section outlines the content of the thesis.

1.1 Research background

Refurbishment is one of the most important topics in the current construction research agenda in the UK (Kemmer & Koskela, 2012). This is mainly because of two reasons. The first one concerns the achievement of the sustainable targets set by the government. According to the Climate Change Act (Department of Energy & Climate Change [DECC], 2008), carbon emissions in the United Kingdom are targeted to fall no less than 80% (by comparison with the 1990 baseline) by 2050. It is known that the built environment is responsible for almost 50% of carbon dioxide emissions (Itard et al., 2008). Provided that a significant amount of buildings, estimated at roughly 70% (Ravetz, 2008) 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 decisive role to meet sustainable targets (Kemmer, Koskela, & Nykänen, 2013). The second reason is the significant part, more than a third, that refurbishment projects represent in the total output of the construction industry (Office for National Statistics [ONS], 2014). Similar factors have been also driving research in Europe and United States.

In the European Union (EU), special attention has been given to the refurbishment of the existing stock in order to achieve the energy and climate objectives of the European Commission (EC, 2010; EC, 2011). The key EU climate/energy targets for 2020, also known as the "20/20/20 targets" (EC, 2010), aim to reduce greenhouse gas emissions by at least 20% (by comparison with 1990 baseline), expand the share of renewable energy sources in the EU final energy consumption to 20%, and improve 20% in energy efficiency. According to the European Commission (EC, 2011), the built environment plays an important role towards the achievement of the EU climate and energy targets as it provides low-cost and short-term opportunities to reduce emissions by improving energy efficiency of buildings.

In the United States, the volume of refurbishment projects is also significant. A survey conducted with 41 organisations, 24 owner and 17 contractor respondents, members of the Construction Industry Institute, showed that refurbishment projects account for nearly 30%

of project cost volume within those companies, i.e., $51 billion dollars out of $180 billion of total project cost (Howard et al., 2009).

It is worth mentioning that refurbishment projects have showed potential in developing countries too. For instance, Devecchi (2010) found out an astonishing number of high-rise empty buildings in Sao Paulo's downtown area in Brazil. Devecchi (2010) suggests that the formulation of a high-rise building refurbishment policy can be seen as an exceptional prospect to mobilize underused resources as well as to restructure the construction industry and to condense the city by increasing land use in central areas.

1.2 Research perspective

Refurbishments have different characteristics in comparison with new build projects (Whiteman & Irwig, 1988; Sanvido & Riggs, 1991; Construction Industry Research and Information Association [CIRIA], 1994; Egbu, 1994; Krizek, Lo, & Hadavi, 1996; Rahmat, 1997; Construction Industry Institute [CII], 2009; Kemmer et al., 2013). This refers mainly to the fact they are carried out in an existing asset that might remain in operation (CIRIA, 1994). Such particular features are likely to increase the complexity innate to construction, as they tend to create challenges that are unique to refurbishments, such as an additional level uncertainty and variability (e.g. the extent and problems of work are not discovered until dismantling and stripping work have began, as-built drawings are often unavailable or inaccurate), particular management issues (e.g. there is a need to manage the interaction between the construction team with users and operations in the existing building), and distinct health and safety concerns (e.g. refurbishment works involving demolition and structural instability are dangerous, and hazardous materials are expected to be encountered in old buildings).

Based on the features mentioned above, it is clear that refurbishments can be generally regarded as complex projects. Several authors have pointed out that production control systems should match to the context in which they are operating (Melles & Wamelink, 1993; Yamin & Harmelink, 2001; Henrich, Tilley, & Koskela, 2005). The same argument is also valid with regard to refurbishment projects, namely, they need appropriate managerial methods, tools, and techniques. For instance, Rahmat (1997) contends that the complex and uncertain nature of refurbishment projects calls for a more flexible planning and control approach. Following the same line of thought, Egbu, Young, & Torrance (1998, p. 319) argue that "refurbishment works demand an ability to deal with non-continuous and complex processes" and also stress that "the process of planning should be adjusted to fit project characteristics".

However, according to the literature (CIRIA, 1994; Krizek et al., 1996; Egbu et al., 1998; McKim, Hegazy, & Attalla, 2000; Singh, 2007; Henrich, 2009), construction organisations have predominantly used traditional practices for managing construction in refurbishment projects (Kemmer et al., 2013). For instance, planning is centralised and lacks involvement of project participants (e.g. subcontractors, labourers, etc.). Managers use pre-estimated plans to push activities on site, regardless of the system status, the communication between planning and production is carried out in a one-way fashion, bar charts are the main planning technique used and the Critical Path Method (CPM) based software packages are utilised to define the critical path and estimate project duration.

The problem is that those managerial practices are not often appropriate to cope with the complex characteristics intrinsic to construction projects (Koskela et al., 2002; Ballard & Howell, 2004). Regarding refurbishment projects, there are evidences in the literature of problems caused due to the use of an incompatible management approach. For instance, Henrich (2009) identified several types of waste on refurbishment sites (e.g. waiting time, double handling, unnecessary transport, etc.) and contended that they stem from the fact "the construction industry has been using outdated production control methods or using them in the wrong context" (Henrich, 2009, p. 98). Difficulties in managing refurbishment projects such as problems in communication between project members leading to schedule overruns (Krizek et al., 1996), poor performance in terms of cost, schedule, and quality, in comparison with new building projects (McKim et al., 2000), failures regarding the fulfilment of customer requirements (Naaranoja & Uden, 2007) have been reported in the literature.

In reality, the root cause of such problems lies deeper than an improper selection of managerial practices and techniques. The underlying reason behind the failure of the conventional construction management is because it is not based on a sound theoretical foundation (Johnston & Brennan, 1996; Howell & Koskela, 2000; Koskela & Howell, 2001). Such a traditional approach is fundamentally based on the transformation theory of production, a reductionist view incapable to deal with complex production settings such as the ones found in the construction sector (Koskela & Howell, 2002). Thus, it is argued that the production management of construction projects needs a more powerful reference basis, i.e., a theory of production suitable to deal with the complexity and uncertainty inherent to refurbishment projects (Kemmer & Koskela, 2012; Kemmer et al., 2013).

In addition, there is another key issue that needs to be considered if one wants to improve the construction management in a refurbishment project, namely, the acknowledgement of the basic features of such projects. As mentioned earlier, those projects are carried out in an existing building that might remain in operation. Therefore, it is contended that any effort to improve the management of refurbishment projects has to take such typical characteristics into consideration so that better results can be achieved.

1.3 Research problem

The construction management in refurbishment projects have not been properly addressed in prior research as the studies on practices applied to the management of this particular environment (Sanvido and Riggs, 1991; CIRIA, 1994; Egbu, 1994; Krizek et al., 1996; Rahmat, 1997, McKim et al., 2000) are scarce and have not been based on an appropriate theory of production (Kemmer & Koskela, 2012; Kemmer et al., 2013). Also, despite being regarded as complex projects, several studies (Krizek et al., 1996; Rahmat, 1997; Egbu et al., 1998; McKim et al., 2000) indicate that construction companies have predominantly used mainstream practices for managing production in refurbishments. Evidence suggests that the use of such inadequate management approach is likely to lead to poor project performance (McKim et al., 2000; Henrich, 2009). Those problems must be addressed.

It is contended that the management of refurbishment works should be underpinned by a theory of production capable of dealing with the complexity intrinsic to refurbishments. It is argued that the use of managerial solutions, in line with concepts and principles of such theory will lead to better project results. It is worth mentioning that the implementation of those solutions should be contextualised to suit the basic features of refurbishments.

Nonetheless, despite its importance for research and practice, theory of production is a topic that has not received much attention by academics (Sanvido and Riggs, 1991; CIRIA, 1994; Egbu, 1994; Krizek et al., 1996; Rahmat, 1997; McKim et al., 2000) that have investigated construction management in refurbishment projects. Only a few studies (e.g. Singh, 2007; Tuholski et al., 2009; Pereira and Cachadinha, 2011) have stressed the importance of a theory of production for managing production effectively. Surprisingly, the majority of research developed on this domain has completely ignored the role of theory in production.

Another issue noted in the literature, focused on construction management in refurbishment projects, is the lack of a formal conceptualisation of this particular type of project. This refers to a conceptual representation that could be useful from a production management stance, and that could also serve as a means to facilitate the understanding of the subject for both academics and practitioners.

Therefore, the research problem to be tackled in this investigation is the lack of a theory-based construction management approach tailored to suit the basic nature of refurbishment projects.

1.4 Aim and research questions

This investigation aims at a method for construction management in refurbishment projects, with the purpose of improving production performance, by indicating appropriate approaches of production control.

The following research questions have been formulated to act as guidance to the achievement of the research aim.

- How should refurbishment projects be conceptualised for supporting appropriate construction management?

- How should a refurbishment project be characterised for providing a foundation to construction management?
- How to apply a theory of production in the construction management of refurbishments?
- How to select practices for managing construction in refurbishment projects?

1.5 Research method

In order to achieve the aim set for this research, a prescription-driven approach named constructive research (also called design science research) is adopted. Basically, it seeks to produce innovative solutions (also termed constructions or artefacts) for relevant practical problems, as well as contributing to the theory in the field being investigated. Several authors (Kasanen, Lukka, & Siitonen, 1993; March & Smith, 1995; Lukka, 2003; van Aken, 2004; Koskela, 2008; Holmström, Ketokivi, & Hameri, 2009; Voordijk, 2009) recommend the use of this method. The main argument is that such research approach focuses on designing an innovative artefact to solve practical problems, rather than being only concerned with the description, analysis, interpretation, and explanation of phenomena. Examples of artefacts designed by researchers who follow this approach are models, frameworks, guidelines, theories, methods, among other constructions intended to solve real-world problems. Further details on the constructive research are provided in chapter 2.

1.6 Focus and scope

The focus of this research is on construction management of refurbishment projects. This means that upstream phases of the project life cycle such as feasibility, design brief, concept, and design development are out of scope and have not been investigated in this study. The same is valid for phases downstream in the construction stage, i.e., use and operation of the building. Also, the research is concentrated on the refurbishment of buildings, thus not including projects related to the infrastructure sector such as roads, bridges, and power plants.

1.7 Content of the thesis

This research is organised in three main parts.

The first part comprises of chapters 1, 2, and 3. Chapter 1 presents the topic addressed in this investigation as well as the research problem, aim and research questions. Also, it introduces the research method selected for the study, sets the focus and scope of the research, and presents the structure of the thesis. Chapter 2 delves into the research methodology and sets out the strategy adopted to achieve the aim of the study. Chapter 3 is dedicated to the literature review and is divided into two sections. Firstly, studies concerning construction management in refurbishment projects are examined. Secondly, topics such as project complexity, theories of production, and managerial solutions used for managing construction are addressed.

The second part of the thesis consists of chapters 4, 5, and 6, focussing on the artefact proposed in the study and follows the steps recommended by the design science research approach. Chapter 4 addresses the development of the method proposed in the thesis. Chapter 5 focuses on the implementation and refinement of the initial version of the method and chapter 6 is dedicated to evaluate its practical utility.

The third and final part, in chapter 7, presents a review of the research problem, aim and research questions, a summary of the research process, the contributions of the study, and the recommendations for future research.

Chapter 2 Research methodology

This chapter presents the rationale behind the selection of design science research (DSR) as the research approach in the study. The main features, outputs, and procedures for implementing the DSR are also discussed. The strategy devised for this investigation is presented along with details about the empirical studies carried out during the research.

2.1 Introduction

According to Crotty (1998, p. 3), methodology is the "strategy, plan of action, process or design laying behind the choice and use of particular research methods and linking the choice and use of methods to the desired outcomes". This definition stresses the importance of defining an appropriate research approach in order to achieve the objectives of the study. There are several models available in the literature serving as guidance on how to define a research methodology (Crotty, 1998; Saunders, Lewis, & Thornhill, 2009; Creswell, 2014). Some models (e.g. Saunders et al., 2009) are more detailed than others (e.g. Crotty, 1998), but in all of them it is clear that there is a hierarchy between the basic elements of a research process, namely, the philosophical assumption, the research methodology or approach, and the methods employed for gathering and analysing data. These components relate to one another and should be aligned with the aim of the research.

The choice of the research methodology should consider the way in which the researcher views the world, and the nature of the research, which is called by Creswell (2014) as philosophical worldview[1]. The philosophical stance guides the researcher in the process of choosing the proper approach to the study proposed. Also, it helps the readers of the thesis to understand why the author has decided upon the research approach and methods he has used in his investigation.

According to Mertens (2005) and Creswell (2014), the four main philosophical worldviews are postpositivism, constructivism, transformative, and pragmatism. The features of each paradigm are summarised in Table 1.

The phenomenon being addressed in this investigation, construction management in refurbishment projects, comprises particular features that should be taken into account to define the most appropriate philosophical worldview for the study. Basically, it refers to complex production settings that involve numerous processes and several stakeholders from different companies. Besides, refurbishments face particular problems, which require in-depth examination in order to enable the development of solutions suited to this project's context.

[1] According to Creswell (2014) distinct terminologies can be also found in the literature to refer to the philosophical worldviews, for instance, paradigms (Mertens, 2005), epistemologies and ontologies (Crotty, 1998), or broadly conceived research methodologies (Neuman, 2009). In this study, the term paradigm is also used.

Table 1 - Basic beliefs associated with the major paradigms (Mertens, 2005)

Basic Beliefs	Postpositivism	Constructivist	Transformative	Pragmatic
Ontology (nature of reality)	One reality; knowable within probability	Multiple, socially constructed realities	Multiple realities shaped by social, political, cultural, ethnic, gender, and disability values	What is useful determines what is true; participants perform reality checks by determining increased clarity of understanding
Epistemology (nature of knowledge)	Objectivity is important; the researcher manipulates and observes in a dispassionate objective manner	Interactive link between researcher and participants; values are made explicit; created findings	Interactive link between researcher and participants; knowledge is socially and historically situated	Relationships in research are determined by what the researcher deems as appropriate to that particular study
Methodology (approach to systematic inquiry)	Quantitative (primarily); interventionist; decontextualized	Qualitative (primarily); hermeneutical; dialectical; contextual factors are described	Inclusion of qualitative (dialogic), but quantitative and mixed method can be used; contextual and historical factors are described, especially as they relate to oppression	Match methods to specific questions and purposes of research; mixed methods can be used

Based on those characteristics, the constructivism paradigm seems to be a good choice. In this worldview it is contended that human beings construct meanings as they engage with the world they are interpreting (Crotty, 1998). Researchers who adopt this view of the world believe that the nature of reality is socially constructed. It is argued that people develop subjective meanings of their experiences with regards to the objects or things (Creswell, 2014). As a result, it is essential to fully understand the context in which people act, as well as to comprehend their perspectives about the phenomenon being investigated. In summary, the followers of this worldview are interested in understanding the complexity inherent to the social interactions existing at certain phenomena, i.e. as is the case in the construction management of refurbishment projects.

In light of the arguments mentioned above, three research strategies were considered initially as potential candidates for undertaking this investigation, namely, case study, action research, and grounded theory. The author took them into account because they fit for the purpose of gaining a full understanding of the context being studied as stressed in the previous paragraph. Case study focuses on describing and explaining an existing phenomenon (Yin, 2003). Action research is also descriptive and explanatory, yet it pays particular attention on the change process within an organisation (Eden and Huxham, 1996). Likewise, grounded theory is useful for predicting and explaining behaviour, although its ultimate goal is to develop theory (Goulding, 2002). Despite being concerned with the understanding of complex phenomena like the one addressed in this investigation, none of those research strategies are sufficient to achieve the aim of this research, which is to develop an artefact, namely, a method for construction management in refurbishment projects. Indeed, they do not see the creation and testing of an artefact as vital because they are more concerned with understanding, explaining, and interpreting the phenomena being studied. Therefore, it is contended that an alternative research approach should be considered, i.e. one that is focused on the design of an artefact with the goal to solve a practical problem. The constructive research approach (also called design science) emerges as an interesting option to be employed in this study because it contains features that fit for that purpose.

Several authors have recommended the use of this research approach (Kasanen et al., 1993; March & Smith, 1995; Lukka, 2003; van Aken, 2004; Koskela, 2008; Holmström et al., 2009; Voordijk, 2009). They argue that it addresses the relevance problem of academic management research. According to those researchers, the customary way to conduct research has not focussed on the design of innovative artefacts to solve practical problems, as is the case in the design science, but normally it has been concerned only with the description, analysis, interpretation, and explanation of phenomena, therefore consisting in what can be defined as explanatory science. While the latter is recognised as an important task towards the development of knowledge, it is argued that it is not enough to solve real-world problems, therefore limiting the potential of practical applications of what is produced in the academia (Kasanen et al., 1993). Similarly to clinical research in medicine, where the objective is to create and test new drugs and treatments, it is argued that the research on construction management should also seek to propose practical and effective artefacts for the problems encountered in the real world (Koskela, 2008). From this perspective, it is contended that researchers following this approach have a pragmatic orientation since they are concerned with improving practice through the creation of an artefact that solves practical problems (Holmström et al., 2009; Hevner & Chatterjee, 2010). According to Dalsgaard (2014), in pragmatism there is a basic principle named "primacy of practice" which says: "the meaning of our conceptualisations of the world - ideas, theories, assumptions, etc. - should be evaluated on the basis of their consequences and implications in practice" (Dalsgaard, 2014, p. 146). Indeed, the practical utility is the most important criterion used to evaluate artefacts in constructive research studies (Kasanen et al., 1993). Therefore, the author considers that this investigation can be underpinned by two major paradigms, namely, constructivism and pragmatism. The latter supports the idea of creating and testing artefacts for solving real-world problems and the former is instrumental for understanding the complexities intrinsic to social phenomena such as the one addressed in this study, i.e. construction management in refurbishment projects.

It is worth mentioning that constructive research has already been used in the field of construction management. There are several examples of studies that have produced artefacts for real-world problems. The Last Planner System[2] of Production Control (Ballard, 2000) is one of the most remarkable illustrations of an artefact created for improving production control in construction projects. Additional examples of artefacts devised by using the design science approach, comprise the development of a tool for diagnosing production management efficiency on construction sites (Henrich, 2009), a conceptual framework for defining customisation strategies in the housing building sector (Rocha, 2011), a conceptual framework to improve methods for developing wayfinding systems and strategies in old and complex hospital environments (Rooke, 2012), an effective benefits realisation process for healthcare infrastructure projects (Sapountzis, 2013), a construction management system based on lean construction and building information modelling (Dave, 2013), and a conceptual framework and best practices for designing and improving construction supply chains (Souza, 2015). The methods of data collection associated to design science research, include the use of interviews with open-ended questions, observations, and analysis of documents (Lukka, 2003). Besides, focus groups can be also used, along with empirical studies to evaluate the solutions devised during the study (Souza, 2015). Therefore, based on the arguments presented above, it is contended that the constructive research approach fits for the purpose of this investigation.

2.2 The constructive research approach

The constructive research (CR) approach is adopted in this study. It is also named as design science research[3] (van Aken, 2004) due to its nature of designing innovative solutions (also known as constructions or artefacts) such as models, frameworks, guidelines, methods, concepts, theories, among other artefacts to solve important real-world problems as well as making a theoretical contribution in the field of study. It is worth mentioning that the terms artefact and method are used interchangeably in this study. The former comes from the research approach whereas the latter stems from the aim set for this investigation.

The CR approach presents particular features that should be taken into account during the development of the study. These are summarised by Lukka (2003, p.2) as follows:

- Focuses on real-world problems felt relevant to be solved in practice;
- Produces an innovative construction meant to solve the initial real-world problem;
- Includes an attempt for implementing the developed construction and thereby a test for its practical applicability;
- Implies a very close involvement and co-operation between the researcher and practitioners in a team-like manner, in which experiential learning is expected to take place;

---

[2] Last Planner System is a registered trademark of the Lean Construction Institute (www.leanconstruction.org).
[3] The constructive research and the design science research are similar. Despite the different nomenclatures, both approaches aim at the same objectives, namely, design and evaluate artefacts with the purpose to solve practical problems while contributing to theory in the field of study.

- Is explicitly linked to prior theoretical knowledge;
- Pays particular attention to reflecting the empirical findings back to theory (Lukka, 2000).

The development of an artefact and its practical evaluation is at the core of the CR approach. To this end, there should be collaboration between the researcher and the practitioners involved in the investigation. The explicit connection to theory is another key element that should be properly regarded by researchers who embrace the design science.

The main output of the CR approach is the development of innovative artefacts for relevant practical problems (Kasanen et al., 1993; March & Smith, 1995; Lukka, 2003; van Aken, 2004; Vaishnavi & Kuechler, 2007; Holmström et al., 2009). These artefacts can be represented in several ways such as concepts, models, frameworks, guidelines, methods, and theories, among others. The types of artefact can vary according to the field of study, for example, an algorithm is considered a classic example of artefact produced on the information technology domain, a new drug or treatment is a typical construct devised in the area of clinical research in medicine and methods are artefacts used in the management realm (Kasanen et al., 1993). However, it is worth mentioning that different domains can also share artefacts of similar nature such as conceptualisations, theories, methods, etc.

This investigation presents a combination of outputs as proposed by March & Smith (1995). These authors suggest the use of design science research on the information technology domain and offer four research outputs in their framework: a) constructs or concepts; b) model; c) method; and d) instantiation. Constructs or concepts represent conceptualisations used to describe a field of study. They are important because they assist the communication within a specific domain by setting terms that will be used by the community (research and practitioners) when describing problems, tasks, solutions or any other activity related to that particular area of interest. A model expresses the existing relation between constructs and it provides a useful representation of how things are. In order to be able to perform a task, a method is used to indicate the sequence of steps necessary to achieve a desired outcome. Finally, instantiations are necessary to evaluate if the solution works or, in other words, they are practical tests of an artefact. Despite being introduced separately, those outputs can be also combined depending on the purpose of the research, for instance, to be able to create a model one has to define the constructs. In this investigation, the aim is to create a method for construction management in refurbishment projects with the purpose to improve production performance by indicating appropriate approaches of production control. To this end, a conceptual model of refurbishment projects is devised and an instantiation is carried out in order to demonstrate the practical functioning of the artefact.

In terms of research process, there are several frameworks available in the literature to assist researchers in the development of CR approach (Kasanen et al., 1993; March &

Smith, 1995; Lukka, 2003; Vaishnavi & Kuechler, 2007; Holmström et al., 2009). These frameworks are summarised in Table 2.

Table 2 – The constructive research process (adapted from Rocha, 2011)

Kasanen et al. (1993)	March & Smith (1995)	Lukka (2003)	Vaishnavi & Kuechler (2007)	Holmström et al. (2009)
Find a problem with practical relevance and that also has research potential		Find a practically relevant problem, which also has a potential for theoretical contribution	Awareness of the problem	Construct an understanding of the problem
		Examine the potential for long-term research cooperation with the target organisation(s)		
Obtain a deep understanding of the topic		Obtain a deep understanding of the topic area both practically and theoretically		
Innovate, i.e. construct a solution idea	Create things that serve human purposes	Innovate a solution idea and develop a problem solving construction, which has a potential for theoretical contribution	Suggestion of a tentative design, further development, and implementation	Development of an initial solution design
Demonstrate that the solution works	Evaluate the performance of things in use	Implement the solution and test how it works	Evaluation of the design against previously defined criteria	Implementation of solution design and refinement of the initial solution design
Show the theoretical connections and the research contribution of the solution		Ponder the scope of applicability of the solution	Conclusion	Development of substantive theory; establish theoretical relevance
Examine the scope of applicability of the solution		Identify and analyse the theoretical contribution		Development of formal theory; strengthen theoretical and statistical generalizability

Despite minor differences in terms of content and level of details, it is safe to say that the sequence of steps proposed by the authors cited in Table 2 shows consistency in terms of research process. For example, it is clear that the CR approach aims at creating and testing of artefacts to solve important practical problems. The need to identify the theoretical contribution of the solution is also a key element of this research approach. Besides, it is worth mentioning that in order to create a suitable artefact it is fundamental to have a deep understanding of the problem being investigated.

Another important element of the CR process that deserves attention is its iterative nature. The artefacts created in the initial stage of the research need to be tested through practical implementations, hence evaluations and refinements can be made as a result. According to Holmström et al. (2009), iterations are essential to improve the artefacts devised initially.

In the next section, the strategy set for this investigation is presented.

2.3 Research strategy

The development of this investigation follows the key steps of the constructive research process as mentioned in the previous section. These are summarised as follows:

- Finding a problem;
- Understanding the problem;
- Developing the artefact;
- Implementing and refining the artefact;
- Evaluating the artefact;
- Assessing the contributions of the artefact.

In this research, the six phases mentioned above are divided into four parts, i.e. artefact development, artefact implementation and refinement, artefact evaluation, and conclusions. An overview of the research process is presented in Figure 1. Further details on the tasks conducted in each phase of the study are described in the following subsections.

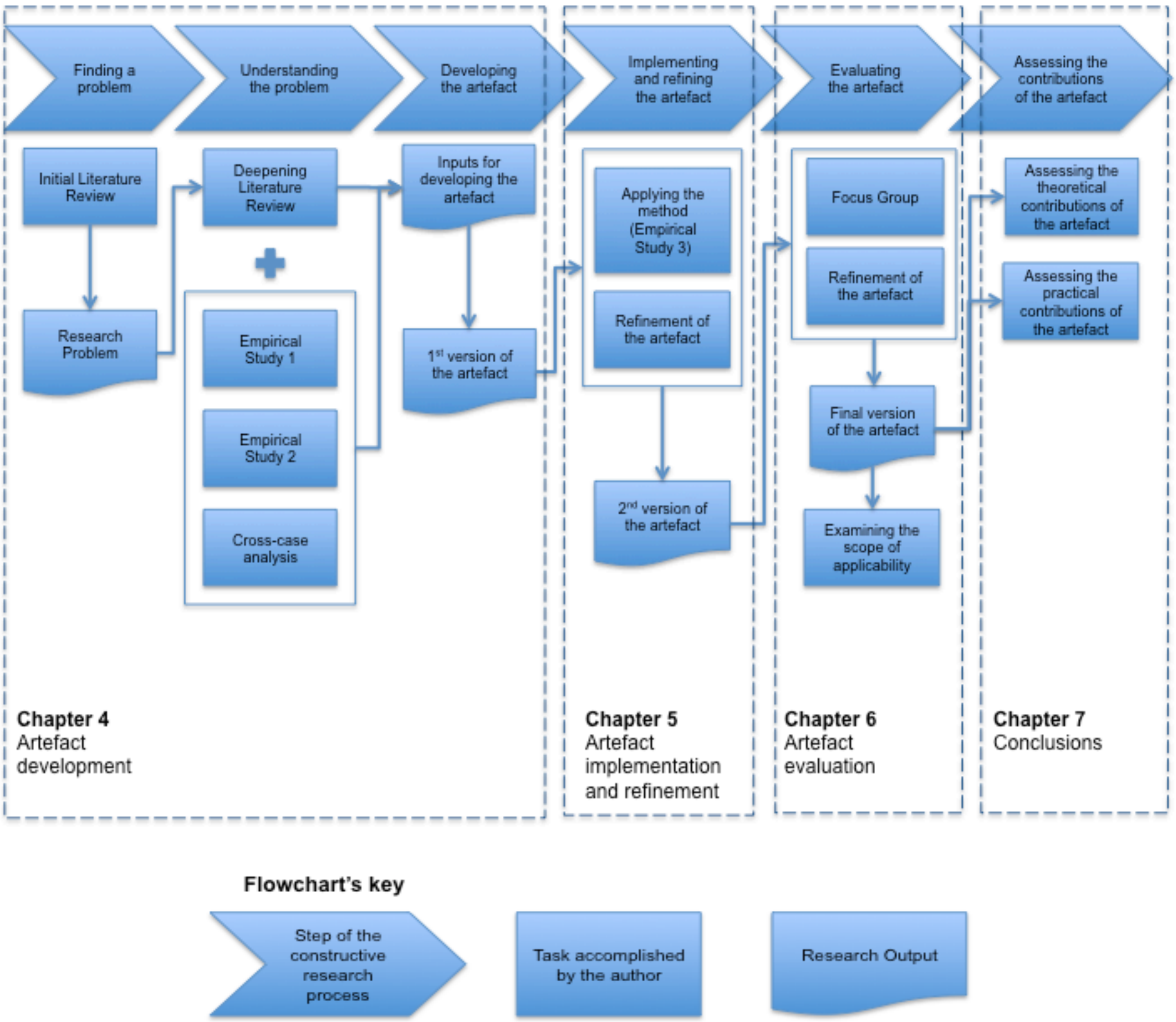

Figure 1 - The research process

2.3.1 Artefact development

The artefact development comprises three phases, i.e. finding a problem, understanding the problem, and developing the artefact. This first part of the research was developed between July 2012 and June 2014. Details about each phase are provided in the next subsections.

2.3.1.1 Finding a problem

The initial phase of the research is dedicated to the identification of the research problem in accordance to the first step of the CR approach, i.e. to find a relevant practical problem, which also has a potential for theoretical contribution (Kasanen et al., 1993). This task was accomplished through a literature review concerning construction management in refurbishment projects. It is noteworthy that there is a huge number of terminologies in the literature to refer to such projects, thus the researcher had to use several keywords to ensure a thorough review. The following keywords were used in the research: refurbishment, renovation, rehabilitation, retrofit, revamp, repair, rebuild, restoration, reconstruction, alteration, conversion, extension, modernisation, upgrade, management, construction, production, project management, construction management, production management, production planning and control.

Such keywords were then examined in the following databases: American Society of Civil Engineers (ASCE) Library, EBSCOhost, Elsevier, Emerald, Google Scholar, ProQuest, Taylor & Francis, Web of Science, Wiley Online Library.

The main academic journals reviewed by the researcher included:

- Automation in Construction;
- Building Research & Information;
- Building and Environment;
- Construction Management and Economics;
- Energy and Buildings;
- European Journal of Operational Research;
- Facilities;
- Health and Place;
- International Journal of Production Research;
- International Journal of Strategic Property Management;
- Journal of Building Appraisal;
- Journal of Construction Engineering and Management;
- Journal of Facilities Management;
- Journal of Management in Engineering;
- Journal of Property Investment & Finance;
- Property Management;
- Structural Survey;

- Total Quality Management.

In addition, the databases of the following organisations were also examined as they might also have publications related to the topic addressed in this study.

- Carbon Trust;
- Centre for Integrated Facility Engineering (CIFE – Stanford University);
- Centre of Refurbishment Excellence (CoRE);
- Constructing Excellence;
- Construction Industry Research and Information Association (CIRIA);
- Construction Industry Institute (US);
- Department of Energy and Climate Change (UK);
- Department for Business, Innovation & Skills (UK);
- Energy Saving Trust;
- Green Construction Board;
- Health and Safety Executive;
- National Refurbishment Centre;
- Sustainable Homes.

Finally, the literature review was expanded by checking the proceedings of academic conferences such as the ones organised by the Association of Researchers in Construction Management (ARCOM), the International Council for Research and Innovation in Building and Construction (CIB[4]), and the International Group for Lean Construction (IGLC).

2.3.1.2 Understanding the problem

This phase comprises three main activities. Firstly, a literature review was conducted in order to gain a deeper understanding of the problems identified in the previous phase. Such a review also served to identify the theoretical background that could be used to underpin the artefact devised in the study. Holmström et al. (2009) argue that the ability of gaining insights from distinct domains to create a novel idea is at the core of the design science approach. The review focused on subjects such as theory of production, management of complex and uncertain projects, and managerial methods to be used as candidate solutions for managing construction in refurbishment projects.

Secondly, two empirical studies were conducted. This was necessary as the literature on construction management in refurbishment projects is scarce. Basically, the aim of these studies was to better understand the characteristics and issues related to construction management in refurbishment projects, as well as identifying opportunities for

[4] CIB is the acronym of the abbreviated French (former) name: "Conseil International du Batiment" (in English this is: International Council for Building). In the course of 1998, the abbreviation has been kept but the full name changed into: International Council for Research and Innovation in Building and Construction. This information was extracted from the CIB website: http://www.cibworld.nl/site/home/index.html.

improvement. The methods used by the companies to manage construction in refurbishments were also examined. Moreover, the researcher seized the opportunity to gather best practices concerning construction management.

The selection of the empirical studies was based on the following criteria: expertise in refurbishments (i.e. the organisations involved in the studies should have large experience in conducting that kind of project), availability of industry partners to engage in the research (i.e. convenience sampling), and diversity of projects. It is worth mentioning that the refurbishment sector comprises different types of projects such as houses, offices, banks, hospitals, department stores, etc. Presumably, there are different characteristics, problems, and management approaches among those projects. Thus, it was decided to conduct the empirical studies in distinct types of refurbishments. While it is recognised that these studies do not cover all situations, it is argued that they were instrumental in providing a comprehensive view about the topic being investigated.

Multiple sources of evidence were used to ensure the reliability as well as the quality of the research (Yin, 2003; van Aken, Berends, & van der Bij, 2007). The methods of data collection utilised in the empirical studies comprised semi-structured interviews, non-participant observations, and documental analysis. Each interview was audio-recorded, transcribed, and saved as an individual file for future reference. Notes on issues related to production management were taken from the observations carried out by the researcher. Documents were classified according to the information described on them. The information gathered by the researcher was triangulated and validated through meetings with project participants for avoiding mistakes and misunderstandings. The data collected was analysed according to the following framework: characterisation of projects, information regarding the existing production planning and control system, typical problems found in those projects as well as best managerial practices and opportunities for improvement. A cross-case synthesis technique (Yin, 2003) was employed for identifying the main differences and commonalities across the empirical studies. In the following subsections, a brief introduction to each study is provided.

2.3.1.2.1 Empirical study 1

This study was carried out within a housing association in England between December 2012 and May 2013. This organisation is responsible to over 18.000 homes across the North West and Yorkshire. A significant number of properties, over a thousand, are refurbished each year. Information was collected from semi-structured interviews, non-participant observations in planning meetings, observations of works on site, and analysis of documents related to the management of production in refurbishments. The information gathered throughout the study was validated through a meeting involving representatives of the housing association and the contractor.

2.3.1.2.2 Empirical study 2

The second empirical study was carried out within a banking organisation in Brazil. It is one of the largest banks in the world, with numerous branches spread over the country. Those facilities have to be maintained and therefore demand constant refurbishments, which are managed by a team of managers. Also, several corporate buildings, which serve as headquarters in Sao Paulo, had just undergone refurbishments at the time the study was undertaken so valuable lessons were shared during the research. This study took place in June 2013 and data were collected from semi-structured interviews, documental analysis, and also from direct observations on site. The researcher conducted a meeting with representatives of the bank in order to validate the research findings.

Thirdly, a cross-case analysis was conducted based on the findings obtained in the empirical studies. This assessment sought to identify the main differences and similarities among the cases investigated. Also, it provided insights that served as inputs for developing the initial version of the artefact proposed in the thesis. Further details about the empirical studies and the cross-case analysis are provided in chapter 4.

2.3.1.3 Developing the artefact

In this phase, the first version of the artefact was addressed. The development of the method proposed in the thesis was based in two sources, namely, the literature review and the empirical studies. The former provided the theoretical background necessary to underpin the artefact, as well as guidelines for managing construction in refurbishment projects. The latter provided valuable information on typical features, problems, managerial approaches, and best practices for managing construction in refurbishment settings. Also, the empirical studies were instrumental in indicating opportunities for improvement.

The method consists of a combination of artefacts such as a conceptual model of refurbishment projects, a framework for project characterisation, and a list of candidate solutions for production management in refurbishment projects. Information on how the method and its components were created is presented in chapter 4.

2.3.2 Artefact implementation and refinement

The implementation and refinement of the artefact devised in the previous phase is addressed in chapter 5. According to van Aken (2004) and Holmström et al. (2009), the artefact devised in a design science research should be tested within the context of its intended use in order to evaluate the performance as well as to enable refinements.

The first version of the method was tested through an empirical study carried out in Northern Ireland. It involved the retrofit of eight nearly similar homes undertaken in five phases. Such a project was considered ideal for research purposes as the knowledge acquired regarding the refurbishment work in one phase could be immediately implemented in the next one. This study was part of a research project focusing on the retrofit of solid wall homes with the purpose to improve energy efficiency, reduce cost, and minimize user's disruption through the construction process.

Throughout the course of the study, the author closely collaborated with the team involved in the research project in order to test and refine the method and its components. For instance, the conceptual model of refurbishments devised previously, was used by the research team during the improvement meeting between the first and second phases of the project, the framework for characterising the project was also applied, and the candidate solutions for improving the management of construction were discussed with project participants.

In order to establish the validity and reliability of the empirical study evidence (Yin, 2003), several methods of data collection were employed by the researcher such as semi-structured interviews, participant observation in planning meetings and trainings, observations on site, and documental analysis. Each interview was audio-recorded, transcribed, and saved as individual file for future reference. Documents were classified as per the information described on them and notes were taken from the observations carried out on site. The data collected was triangulated and validated through a workshop with project participants to corroborate the research findings. In addition, the researcher introduced the artefact devised in the thesis (i.e. the method for construction management in refurbishment projects) to the participants of the project during an improvement meeting in order to get their feedback on the utility of the artefact.

Due to the research limited timeframe and unforeseen circumstances faced during the development of this empirical study, the researcher could not finalise the implementation phase as planned. However, the partial practical test of the method and its components enabled major refinements. Hence, a second version of the artefact was generated. This improved version of the artefact was then submitted to an additional evaluation. In the following section, further details on such evaluation are provided.

2.3.3 Artefact evaluation

A focus group was formed with the purpose of evaluating the second version of the method. It took place in Norway in June 2015 and it was carried out in partnership with a contractor. The selection of the company and participants of the focus group was based on the following criteria: expertise in refurbishments, familiarity with the theory of production addressed in this research, and availability to contribute to the research (i.e. convenience sampling). The company has large experience in managing construction in refurbishment projects. Likewise, participants invited to attend the focus group, were also managers who had knowledge of such projects. They are also well informed about the concepts and principles of lean construction because the company has been practicing this philosophy of production on their sites for several years. The goals of the focus group are described as follows:

- Evaluate the conceptual features of the artefact;
- Evaluate the applicability of the artefact within the organisation.

The evaluation conducted through the focus group, led to additional refinements in the artefacts devised during the study, hence improving the design of the artefact. The final version of the method is described after the presentation of the outcomes of the focus group. This is followed by the examination of the scope of applicability of the method. This analysis aimed at assessing the extent to which the artefact devised in this study might be transferable to other contexts, other than the ones addressed in this investigation. It was based on three sources of evidence, namely, the practical test of the artefact carried out during the third empirical study, the evaluation conducted in the focus group, and the reflection of the author on findings from those assessments. Further details about the evaluation of the method are presented in chapter 6.

2.3.4 Assessing the contributions of the artefact

The last phase of the constructive research approach involves the assessment of the contributions of the artefact, which is conducted from two different perspectives, namely, theoretical and practical. It was based on the last version of the method to ensure that all refinements incorporated to the artefact throughout the study could be assessed. In order to evaluate the theoretical contributions, the author looked at how findings that were unearthed in the previous phases of the research, connected to the prior theory and basically means to determine what this particular study can add to the existing literature (van Aken et al., 2007). The analysis of the practical contributions, aimed at exploring the benefits brought by the artefacts devised in the research from an industry viewpoint. This assessment was completed by looking at three sources of evidence, i.e. results from the practical test of the method, perceptions of experienced practitioners, and the reflection of the author on findings of the research. Further details are presented in chapter 7.

Chapter 3 Literature Review

This chapter consists of two main parts. Firstly, a critical analysis of previous research on refurbishment projects, with a particular focus on construction management, is conducted. Secondly, the theoretical background used to underpin the artefact proposed in the thesis, i.e. the method for construction management in refurbishment projects, is presented. It is worth mentioning that several parts of this literature review were expanded from what was presented in Kemmer et al. (2013).

3.1 On refurbishment projects

The definition of refurbishment adopted in this research is of paramount importance. This study follows the interpretation made by Egbu et al. (1998, p. 316) who say that "refurbishment refers to such works as improvements, 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, Leung, Yiu, & Wong 2003), cost modelling (Lehtonen & Kiiras, 2010), the use of information technology (Okoroh & Torrance, 1999; Caccavelli & Gugerli, 2002; Dulung, 2007; Ho, 2009; Ho & Fischer, 2009; Lee, 2012); the engagement and perspectives of users (Holm, 2000; Miller & Buys, 2008), material waste management (Li & Yang, 2014), knowledge management (Liu, 2015; Lundberg & Lidelöw, 2016), among others topics.

In addition, due to the important role that refurbishment projects play in meeting sustainability targets, a recent increase in the amount of research aiming at better understanding, as well as improving the way that those projects are designed, procured, built, and operated, is also found in the literature (Itard & Meijer, 2008; Kelly, 2009; Department for Business, Innovation and Skills [DBIS], 2010; DBIS, 2011; Mansfield, 2009; Mansfield, 2011; Swan & Brown, 2013; Swan, Ruddock, Smith, & Fitton, 2013). Also, in line with the trend towards improved sustainability, academic journals have promoted special issues addressing the role of refurbishment projects in improving energy efficiency. For example, the journal Structural Survey published recently two special issues focusing on topics concerning the relationship between sustainability and building adaptation, one called "Building adaptation and sustainability" (Wilkinson, 2012) and another titled "Key challenges of managing adaptation and retrofit projects" (Ahadzie & Ankrah, 2014). The journal Building Research & Information (BRI) has been also contributing to this discussion over time through special issues, for instance, the two most recent publications on this topic include an issue titled "Urban retrofitting for the transition to sustainability" which provides a social-technical approach of the challenges of urban retrofit (Dixon & Eames, 2013) and another one called "Energy retrofits of owner-occupied homes" focusing on the importance of considering the point of view of people involved in such projects into the policies and practical measures concerning to those retrofits (Gram-Hanssen, 2014).

However, there is a missing link in the refurbishment's research agenda. Despite the vast number of research initiatives focused on improving this sector, it is safe to say that the specific topic of management of refurbishment works has not been properly addressed. There are few studies delving into the way construction companies have been managing construction in such projects. Thus, further investigation is needed to better understand how refurbishments have been managed in order to promote the necessary improvements.

This initial part of the literature review is divided into two main sections. The first one aims at introducing the context in which refurbishment projects take place as well as showing the traditional approach used by companies for managing construction. In the ensuing section, the efforts made by previous researchers for improving the management of refurbishment projects are described. Conclusions are presented after the end of the second section.

3.1.1 On construction management in refurbishment projects

What are the typical characteristics of refurbishment projects? How is construction usually managed in those particular settings? What are the practical implications of such traditional management approaches? These questions are the focus of this section.

3.1.1.1 The typical characteristics of refurbishment projects

Refurbishments present different features in comparison with new build projects (Whiteman & Irwig, 1988; Sanvido & Riggs, 1991; CIRIA, 1994; Egbu, 1994; Krizek et al., 1996; Rahmat, 1997; CII, 2009). According to CIRIA (1994), the existing asset is the most distinguishable characteristic. Another distinct feature concerns to the possibility of carrying out a project in a building that remain in operation (CIRIA, 1994). Such particular features tend to increase the complexity intrinsic to construction because they are likely to produce management issues that are unique to the refurbishment project environment (Table 3).

There is a consensus in the literature that production control systems should match to the context in which they are operating (Melles & Wamelink, 1993; Yamin & Harmelink, 2001; Henrich et al., 2005). Several authors who carried out research on the refurbishment domain agree to that argument. According to Sanvido and Riggs (1991), appropriate management procedures should be adopted to cope with the intrinsic features of refurbishments in order to enable the achievement of project objectives. CIRIA (1994) contends that such specific characteristics influence the selection and control of all kinds of resources, including managerial means. Egbu, Young, and Torrance (1996) stress the importance of adopting proper management practices so improved efficiency and effectiveness of refurbishment operations can be achieved. Following the same line of thought, Egbu et al. (1998, p. 319) argues that "refurbishment works demand an ability to deal with non-continuous and complex processes" and also emphasise that "the process of planning should be adjusted to fit project characteristics".

Table 3 - Typical characteristics of refurbishment projects

Management issues	Refurbishment features	References
Additional level of uncertainty and variability	Unforeseen conditions more prominent. The amount of problems are not revealed until dismantling and stripping work have started	Quah (1992); Singh (2007); Howard et al. (2009)
	As-built drawings are often unavailable and when they are available normally they are inaccurate	Sanvido and Riggs (1991); Quah (1992); CIRIA (1994);
	Discovery of unforeseen conditions continue to happen during construction phase	CIRIA (1994), Krizek et al. (1996)
	Project scope can be unclear due to limited information about the existing building	Sanvido and Riggs (1991); CIRIA (1994)
Particular management challenges	Small labour intensive operations spread out in the existing building, which is commonly occupied	Quah (1992), Rahmat (1997), Ho (2009)
	Operational constraints related to the existing facility, hence greater need to interface with the existing operations in the building, tenants, neighbours, maintenance and construction personnel	Sanvido and Riggs (1991); CIRIA (1994); Krizek et al. (1996); Howard et al. (2009)
	Refurbishments might happen in a occupied building, hence temporary structures may be necessary to safeguard users and operations in the existing building	CIRIA (1994), Krizek et al. (1996), Rahmat (1997)
	Time is usually constrained in refurbishment projects due mainly to interference with building occupation and operation	Sanvido and Riggs (1991), Rahmat (1997)
	Refurbishments involve a high number of constraints such as space limitations (e.g. storage, new equipment, construction), restricted access, pollution control, etc.	Whiteman and Irwig (1988); CIRIA (1994), Rahmat (1997) Krizek et al. (1996), Singh (2007)
Distinct health and safety concerns	Dangerous work, specially when it involves demolition and structural instability	CIRIA (1994); Egbu (1995); Anumba et al. (2004)
	Hazardous material (e.g. asbestos) might be encountered in the existing building	Sanvido and Riggs (1991); CIRIA (1994); Egbu (1997)
	Safety issues due to the interface of workers with existing operations in the building and involvement of building users who may include the public	CIRIA (1994); Howard et al. (2009)

However, several studies indicate that construction organisations have predominantly used traditional management practices (e.g. Critical Path Method) for managing construction in refurbishment projects (CIRIA, 1994; Krizek et al., 1996; Rahmat, 1997; Egbu et al., 1998; McKim et al., 2000; Singh, 2007; Henrich, 2009). The problem is that the use of such a management approach is often not appropriate to deal with the dynamic nature of complex production settings (Laufer et al., 1996; Koskela et al., 2002; Ballard & Howell, 2004). In the following section, further details are provided regarding this.

3.1.1.2 The traditional construction management approach utilised in refurbishment projects and its practical implications

The report developed by Sanvido and Riggs (1991), the guide produced by CIRIA (1994), the studies developed by Krizek et al. (1996), Rahmat (1997), McKim et al. (2000), Singh (2007), Henrich (2009), along with the research led by Egbu and his colleagues from 1994 to 1999 provide a panorama on construction management in refurbishment projects. This refers to information concerning production planning and control processes, and managerial practices and techniques usually used for managing construction in refurbishment projects.

Sanvido and Riggs (1991) conducted a research with the purpose to identify the effective management techniques used in refurbishments, as well as the critical factors to the success of a project. With regard to the former, the researchers found limited information, but preplanning (in strategic and operational terms) was highlighted as an important technique. Among the critical success factors, the need to have in place the right project team was deemed as the most important. According to those authors, this factor goes beyond than just having a team with appropriate experience and skills, this also involves a team with the right chemistry (i.e. ability to work together) and attitude, flexibility and responsiveness to cope with the typical changes inherent to refurbishment projects and also refers to a team that is put together at the beginning of the project and stays together until the end of it. Other critical success factors that are identified include contract incentives, partnering arrangements, scope management, plant knowledge, communication, special procurement and preplanning strategies, and high level management support.

The study developed by Egbu (1994) delved into aspects concerning the management of refurbishment works within the UK construction industry. Through semi-structured interviews with managers, and a postal questionnaire addressed to refurbishment organisations, Egbu acquired an overview of particular issues and characteristics related to the management of this complex environment. For instance, 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 features in managing refurbishment work. In turn, cost control, dust control, the influence of tenants on the regular progress on site, pricing of the works, and variation/change orders to the works are identified as the most challenging refurbishment characteristics faced by managers. Furthermore, Egbu (1995) investigated 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. Table 4 presents the top ten ranking.

Table 4 - Management tasks perceived as most difficult in managing refurbishment works (adapted from Egbu, 1995)

Rank	Job dimension (tasks)
1	Forecast and planning
2	Analysis of project risk and uncertainty
3	Competitive tendering
4	Budgetary control
5	Managing time
6	Quality control and assurance
7	Health and safety
8	Site security
9	Use of computer technology
10	Managing conflict / crisis

Egbu et al. (1996) and Egbu et al. (1998) identified the planning and control techniques used by refurbishment organisations. Data was collected through a case study carried out in a hospital and hotel refurbishments (Table 5).

Table 5 - Planning and control techniques used in refurbishment projects (adapted from Egbu et al., 1996; Egbu et al., 1998)

Rank	Hospital Refurbishment	Hotel Refurbishment
1	Schedules	Bar chart
2	Critical Path Method (CPM)	Project cost-value reconciliation
3	Project cost-value reconciliation	Labour (actual and forecast) reconciliation
4	Bar chart	Material (actual versus forecast) reconciliation
5	Milestone date programming technique	Schedules
6	Labour (actual versus forecast) reconciliation	Plant (actual versus forecast) reconciliation
7	Plant (actual versus forecast) reconciliation	Critical Path Method (CPM)
8	Material (actual versus forecast) reconciliation	Man-hour (plan analysis and update)
9	Computer: expert system techniques	Milestone date programming technique
10	Programme evaluation and review techniques (PERT)	Programme evaluation and review techniques (PERT)
11	Graphical evaluation and review techniques	Computer: simulation techniques
12	Man-hour (plan analysis and update)	Computer: expert system techniques
13	Computer simulation	Graphical evaluation techniques

Yet, survey conducted by Rahmat (1997) among 103 construction firms provided additional evidence on the type of planning techniques most used in refurbishments (Figure 2).

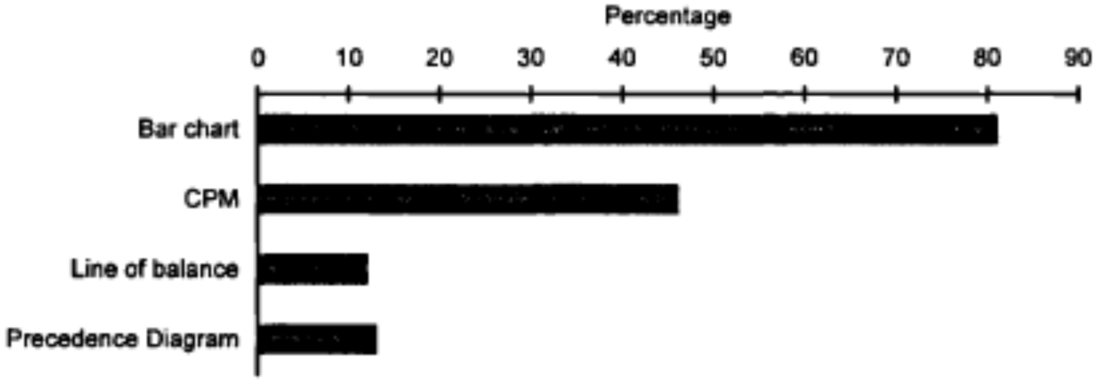

Figure 2 - The planning techniques commonly used by refurbishment contractors (Rahmat, 1997)

Table 5 and Figure 2 show clearly the predominance of traditional planning techniques such as bar charts and Critical Path Method (CPM). Yet, the use of such techniques for managing construction in refurbishment projects, is mentioned in the guide to the management of building refurbishment produced by CIRIA (1994), and also in the studies developed by Krizek et al. (1996) and McKim et al. (2000).

Singh (2007) conducted interviews with contractors and subcontractors involved in renovation projects and learned that the production planning process is carried out on an informal basis. No formal documentation or standardized process was identified for dealing with the constraints intrinsic to such projects (e.g. poor as-built drawings, unforeseen conditions, presence of hazardous materials, etc.), regardless of the influence that those project conditions might have on project performance (Krizek et al., 1996; McKim et al., 2000; Singh, 2007).

Some could contend that the aforementioned managerial practices are no longer in use, implying that the management of refurbishment works has evolved. However, the study carried out by Henrich (2009) shows that it has not. Findings demonstrate that managerial practices utilised for managing construction in refurbishment projects remain inappropriate.

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, there is no involvement of stakeholders (subcontractors, suppliers, labourers) in the creation of plans and the Critical

Path Method (CPM) is used as the main tool for production planning and control. Planning is centralized and contains excessive details at early stages, as a result constant and laborious updates are needed since the plan became easily out of date. Furthermore, managers use pre-estimated plans to push activities to production regardless the system status and the communication between planning and production is done in a one-way fashion. Control follows the thermostat model, namely, action is taken only when a variance against the standard performance is identified. Also, there is no evidence of a continuous improvement programme implemented on site. As a result of the use of those inadequate managerial practices, Henrich (2009) identifies several types of waste within those 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. It is argued that such wastes are likely to result in low productivity, project delays, cost overruns, and tenant's annoyance.

Indeed, there is evidence in the literature showing that the performance of refurbishment projects is not satisfactory. Krizek et al. (1996) conducted an investigation in a multiphase reconstruction project in the United States and pointed out difficulties in communication between project members, as well as problems to manage production leading to schedule overruns. Rahmat (1997) examined 67 refurbishment projects and found out that 53.3% exceeded the target cost and 52.5% exceeded the target time. McKim et al. (2000) carried out a survey in Canada and reported the poor performance of reconstruction projects in terms of cost, schedule, and quality, in comparison with new building projects. In all studies aforementioned, tools such as bar charts and CPM were reported as the main techniques adopted. Finnish renovation projects also presented poor project performance in terms of cost, time, and also failures concerning the fulfilment of customer requirements (Naaranoja & Uden, 2007). In conclusion, as noted by Henrich (2009, p. 98), "the construction industry has been using outdated production methods or using them in a wrong context".

The findings mentioned above imply that the use of conventional management methods leads to wastes and ultimately poor project performance. This insight poses the following question: why does the traditional construction management approach fail? A close look at the literature on construction management reveals that the root cause of such failure lies deeper than an inappropriate selection of managerial practices. Next, the reasons behind the failure of the traditional management approach in construction projects are addressed.

3.1.1.3 Why traditional construction management approach fails

The findings from the study conducted by Henrich (2009) presented in the previous section provide a comprehensive description of the traditional construction project management approach used in refurbishment projects. Clearly, there is an emphasis on managing tasks on site by applying scheduling, particularly by implementing the Critical Path Method (CPM).

However, it is worth mentioning that the use of CPM for production planning and control in construction projects has been criticised for a long time. Peer (1974) cites limitations for site management by arguing that plans are quickly out of use, even prior the start of works on site. He also contends that the lack of adherence to reality demands permanent and time-consuming adjustments of the plan to real situations. Birrel (1980) argues that CPM does not produce satisfactory results because it is not compatible to the essence of the construction process. The following observation clarifies such incompatibility:

> When such an approach is used to plan a process (e.g. the construction process) that is dynamic and contains many individual resources which are controlled by a diverse group of human participants, the 'plan it and pass it on' attitude is insufficient for successful execution of the process. (Birrel, 1980, p. 403).

According to Johnston and Brennan (1996), this prevailing approach based on planning refers to a management style called management-as-planning. The underlying assumption is that projects can be successfully managed by the production and implementation of plans. While effective for managing simpler projects, this approach is not capable to deal with projects subjected to high levels of uncertainty (Laufer, Denker, & Shenhar, 1996).

The traditional planning is not the only approach that is criticised for not being suitable for quick, uncertain, and complex projects. The use of classic project controls (i.e. thermostat model) is also considered ineffective for controlling such projects. Howell and Ballard (1996) argue that the thermostat model does not provide the necessary information for effective decision-making, since its emphasis is on project outcomes as opposed to management processes (e.g. it fails to monitor the workflow). Koskela and Howell (2002) stress that such a model does not focus on finding the reasons for deviations. As a result, the root causes of problems are not eliminated. Ballard and Howell (2004) contend that the main problem with the conventional construction project management (i.e. detailed CPM schedules, thermostat model, competitive bidding) is that it "assumes that variability in workflow is outside management control and so does not attempt to systematically reduce variability" (Ballard and Howell, 2004, p. 40).

It seems clear that the traditional management approach is not appropriate for managing refurbishment projects. However, despite the several shortcomings aforementioned, there is a fundamental issue that has not been referred to, as yet, namely, theory. Koskela (2000) argues that traditional construction project management fails because it is not based on a sound theoretical foundation. He contends that this approach is essentially based on the transformation theory of production, a reductionist view incapable to cope with complex production settings such as the ones found in the construction sector. He concludes that construction project management needs a more powerful reference basis, i.e. a theory of production capable to deal with the intrinsic construction peculiarities.

In summary, the traditional project management approach fails because it neglects the context in which the refurbishment projects take place and because it is not based on a proper theory of production. The importance of recognising refurbishments as complex projects, as well as having a sound theory of production as a reference basis for managing and improving construction management, is addressed in the second part of this chapter.

3.1.1.4 Discussion

There are three main aspects worth stressing based on the literature review presented so far. The first argument concerns the context in which refurbishments take place. It refers to the particular features that can be considered as part of the nature of refurbishments, i.e. the fact that they are carried out in an existing asset that might remain in operation. Such distinct characteristics produce a complex project environment that is subjected to an additional level of uncertainty and variability, particular management challenges, and distinct health and safety concerns. It is argued that those peculiarities have to be taken into account when defining the construction management approach to be implemented in a project.

The second point concerns the mismatch between the usual construction management approach and the refurbishment context. Companies have been using traditional methods to manage complex projects. Findings suggest that the use of such incompatible approach causes several problems on refurbishment sites and results in poor project performance.

The third aspect refers to the lack of a sound theoretical foundation underpinning the current management practices. As a matter of fact, theory is a topic generally neglected in prior research on construction management in refurbishment projects. It is contended that a more powerful reference basis is needed to underpin the management of refurbishment works, i.e. a theory of production capable to cope with refurbishment features.

The studies cited earlier provided an overview on how construction is customarily managed in refurbishments as well as the problems found in such projects. Nevertheless, it is worth mentioning the efforts made by previous researchers for improving the management of refurbishment projects. They refer to the prescription of artefacts such as guidelines, the most common type of artefact found in the literature, and other types of constructions such as a framework, a method, among others. Next, those artefacts are examined.

3.1.2 On artefacts for improving construction management in refurbishment projects

Several artefacts have been conceived with the purpose to improve the performance of refurbishment projects. They refer mainly to guidelines on project management and also, in minor quantity, to other types of constructions such as a scheduling technique designed for managing renovation work (Whiteman & Irwig, 1988), a framework that calculate the impact of constraints on the duration of activities (Singh, 2007), a method to identify occupant interactions in occupied buildings (Ho, 2009), and a process for conducting front end planning in renovation projects (CII, 2009). Those artefacts are introduced as follow.

3.1.2.1 Guidelines

Guidelines are the most common type of artefact devised with the purpose to improve the performance of refurbishment projects. In total, 129 guidelines were found in the literature. Basically, there are two types of guidelines, which are classed by the author as general and specific. The former are meant to suit all types of refurbishments, while the latter refer to specific project contexts such time-dominated projects, occupied buildings, refurbishments involving demolition and structural instability, hospitals, and retrofits.

Examples of those two categories of guidelines are provided as follow. They were selected according to their relevance to the topic addressed in this study, i.e., they focus on issues related to construction management in refurbishment projects.

3.1.2.1.1 General guidelines

General guidelines can be found mainly in the work developed by CIRIA (1994) and also in the research carried out by Egbu (1997), Egbu et al. (1998), Krizek et al. (1996), McKim et al. (2000), and Mitropoulos and Howell (2002). The following list summarises the main recommendations proposed in the aforementioned studies.

- Promote close collaboration between the parties, i.e., client, contractors, designers, building managers, etc., and identify decision makers and their areas of responsibility (CIRIA, 1994);
- Select the project team early (Egbu, 1997; Mitropoulos & Howell, 2002). Encourage early involvement of the construction team with the design (CIRIA, 1994);
- Make sure that all project participants are aware of project objectives (CIRIA, 1994);
- Assess alternative contract strategies for the procurement of design and construction work against project objectives, constraints and risks (CIRIA, 1994; Egbu, 1997);
- Conduct extensive investigation work on the existing building (CIRIA, 1994);
- Improve the quality and timing of relevant information for the works (Egbu et al. 1998);
- Accelerate the discovery of the existing conditions and constraints (Mitropoulos & Howell, 2002);
- Reduce and if possible eliminate uncertainty in the programme with the purpose to meet project objectives (CIRIA, 1994);
- Allow time and money in the plan for extensive consultation with users, neighbours, planning authorities, etc. (CIRIA, 1994);
- Work with experienced people who have a good track record on refurbishment projects, e.g., a specialist contractor (CIRIA, 1994; Krizek et al., 1996);

- Determine the procedures for information flows among the parties involved in the project to make clear the consequences of changes among project participants (CIRIA, 1994);
- Increase the percentage level of design completion before commencement of the works (Egbu et al., 1998);
- Contractors must be fully informed of the constraints under which they will have to work (Krizek et al., 1996);
- Set up a management system and contractual procedures compatible with project objectives. Make sure they are sufficiently flexible to be able to cope with changes (CIRIA, 1994; Egbu, 1997);
- Plans of work and work schedules must be realistic and must be seen to be so by those who have to work to them (CIRIA, 1994);
- Assist clients in the decision making process by providing the cost implications of each design option on a timely manner, including any consequent repercussion in the normal operations of the building and users (CIRIA, 1994);
- Provide assistance to users in managing disruptions (CIRIA, 1994);
- Provide contingencies in programmes and estimates to deal with unforeseen situations and users of the building (CIRIA, 1994);
- Integrate the operational facility's schedule of the existing facility into the construction schedule (McKim et al., 2000);
- Use rapid prototyping (Mitropoulos & Howell, 2002).

Despite addressing important issues related to the management of refurbishment works, the general guidelines do not cover all situations encountered in such projects. Since they approach refurbishment from a general perspective, they overlook the fact that refurbishments are undertaken in several sectors of the construction industry, such as housing, hospitals, offices, etc. Presumably, there are different approaches to different projects. Some authors perceived the necessity of devising prescriptions tailored to particular project contexts and this insight led to the development of the specific guidelines.

3.1.2.1.2 Specific guidelines

Specific guidelines refer to recommendations for improving the management of refurbishment in particular project settings. For example, there are guidelines related to refurbishment of time-dominated projects (CIRIA, 1994), occupied buildings (CIRIA, 2004), projects involving demolition and structural instability (Anumba, Marino, Gottfried, and Egbu, 2004), hospitals (Worley & Hohler, 2008; Lahtinen, Salonen, Lappalainen, Huttunen, & Reijula, 2009; Ross et al., 2011), and retrofits (FutureFit, 2011; Technology Strategy Board [TSB], 2013; Willey, 2013; TSB, 2014). Examples of these guidelines are provided in the following subsections.

3.1.2.1.2.1 Refurbishment of time-dominated projects

The refurbishment of time-dominated projects is addressed in the guide produced by CIRIA (1994, p. 31) through the following guidelines:

- Exhaustive preparation;
- Extremely detailed programmes and resources lists, with a level of detail almost never found in new work;
- Extensive communication of the plan and progress against the plan, perhaps even hour to hour, both within the refurbishment team and to affected users;
- Provide realistic contingencies in plans, programme and resources, including options and fall-back positions;
- Organising to allow fast reactive management responses, for example by delegating authority for decisions, including commitment of contingency monies and by having sophisticated communication systems;
- Having an ultimate, but confidential, fall back of an operational contingency plan if the time window is exceeded.

3.1.2.1.2.2 Refurbishment of occupied buildings

Another example of specific guidelines refers to the refurbishment of occupied buildings. The guide produced by CIRIA (2004) provides recommendations on several topics related to this particular situation found in refurbishment projects. The subjects covered in the guide are described as follows along with examples of guidelines concerning each topic.

- Project planning
    - The client should appoint a planning supervisor for health and safety issues and should also consider appointing an expert on risk and value management (CIRIA, 2004, p. 20);
    - The client should choose a procurement route compatible with their objectives for the refurbishment and the nature of the project (CIRIA, 2004, p. 21);
    - In order to conduct a proper briefing talk to all parties likely to be affected by the refurbishment (CIRIA, 2004, p. 23);
    - The form of contract is critical in establishing cooperation and avoiding confrontation (CIRIA, 2004, p. 31).
- Time and programming
    - The programme for refurbishment should be coordinated with occupants' activities. Effective time management can reduce conflicts between occupants and builders (CIRIA, 2004, p. 33);
    - Establish a practical and efficient project programme (CIRIA, 2004, p. 34);
    - Involve builders as early as possible to avoid problems later (CIRIA, 2004, p. 34);

    - Marked-up building plans may be easier to understand than complex programme charts (CIRIA, 2004, p. 41).
- Project team
    - The project team should collaborate and understand each other’s roles and responsibilities, within an appropriate procurement route (CIRIA, 2004, p. 42);
    - Make sure that the firms and individuals have the capability to deliver (CIRIA, 2004, p. 46);
    - Select procurement routes and forms of contract that reinforce cooperation not confrontation, and involve the builder as early as possible (CIRIA, 2004, p. 47);
    - Develop “what if?” scenarios in advance (CIRIA, 2004, p. 49).
- Communication
    - Develop a communication plan describing who is responsible for communicating with which stakeholders, and what resources will underpin this work (CIRIA, 2004, p. 54);
    - Try to make sure that all stakeholders have the information they need, without releasing contentious material (CIRIA, 2004, p. 54);
    - Make every effort to ensure that people who are affected by the refurbishment know what is happening, and allow them to say what they think (CIRIA, 2004, p. 56);
    - Put effort into involving the construction workforce in the project (CIRIA, 2004, p. 59);
    - Get all the people working on the refurbishment project into a shared office (CIRIA, 2004, p. 60);
    - Carry out post-project reviews of project records in order to learn by analysing what worked well and less well (CIRIA, 2004, p. 61).
- Health and safety
    - Health and safety management should be integrated with all other aspects of the project (CIRIA, 2004, p. 63);
    - Keep building occupants (and the public) away from any potential hazards (CIRIA, 2004, p. 64);
    - Involve all parties in formulating the health and safety plan – and follow it (CIRIA, 2004, p. 68);
    - Carry out surveys to identify the presence of materials that may be hazardous (CIRIA, 2004, p. 71);
    - Occupants, builders, and members of the public must have clear routes out of the building in case of emergency (CIRIA, 2004, p. 73).

- Circulation and site boundary
    - The project team need to plan access before starting work on site. They should map out emergency access routes, routes for vehicles, and contractor routes inside the building (CIRIA, 2004, p. 77);
    - Set aside an external area for the contractor's use, to avoid conflict with the occupants (CIRIA, 2004, p. 80);
    - Establish physical boundaries between the internal areas for the builders and occupants (CIRIA, 2004, p. 81);
    - Minimise inconvenience to occupants (CIRIA, 2004, p. 84);
    - Ensure the builder has freedom to deliver materials in the most efficient manner to minimise disruption (CIRIA, 2004, p. 86).
- Security
    - Separate the occupied and builders' areas and avoid insecure access routes between them, and ensure that the builder's site area has a secure boundary (CIRIA, 2004, p. 91);
    - Establish an access control system to ensure that only authorised people can get into the builder's working area (CIRIA, 2004, p. 92);
    - Ensure that construction workers wear identifiable clothing (CIRIA, 2004, p. 93);
    - Avoid creating temporary access routes during refurbishment (CIRIA, 2004, p. 96).
- Noise, dust and other pollution
    - Eliminate or reduce the creation of noise, dust and other pollution (CIRIA, 2004, p. 97);
    - Create the noise, dust and other pollution at times when it does not affect business continuity (time separation) (CIRIA, 2004, p. 97);
    - Ensure that occupants and business operations are well insulated from the noise, dust and pollution (physical separation) (CIRIA, 2004, p. 97);
    - Select building methods that create less noise, dust and pollution (CIRIA, 2004, p. 100).

3.1.2.1.2.3 Refurbishment involving demolition and structural instability

The research developed by Anumba et al. (2004) investigated the main factors related to accidents in refurbishments involving demolition works. They identified the key issues to be addressed by health and safety management strategies and undertook a comparative study of Italian and UK refurbishment sites. The following recommendations for dealing with projects involving demolition and structural instability were devised by those authors.

- Prior to undertaking any demolition activity on site that may interfere with the structural stability of the building, preliminary surveys and site investigations have to be carried out by structural engineers as well as specialist demolition contractors (Anumba et al., 2004, p. 9);

- Refurbishment projects involving demolition activities require the appointment of competent and qualified professionals who are going to implement health and safety in the development of any stage of the project, from design to execution phase (Anumba et al., 2004, p. 9);
- There is the need for a key figure in charge of the coordination of all structural information elaborated during the design phase and of the supervision of the design of temporary works and of the planning of demolition activities (Anumba et al., 2009, p.9);
- Clients need to be more involved in the health and safety management of the refurbishment projects they are procuring (Anumba et al., 2004, p.9);
- Communication of project information and the client's health and safety requirements has to be considered a priority issue for the development of effective health and safety management strategies (Anumba et al., 2004, p.10);
- New communication systems such as drawing-based method statements or the use of pictures or video for health and safety training is strongly recommended for supporting health and safety education of foreign language workers (Anumba et al., 2004, p.10).

3.1.2.1.2.4 Refurbishment of hospitals

Interestingly, the majority of guidelines cited in this section were extracted from journals of medicine (Worley & Hohler, 2008; Lahtinen et al., 2009; Ross et al., 2011). The reason for that is because the studies related to refurbishment of hospitals have addressed other subjects than construction management itself, such as the minimisation of material waste derived from the construction of healthcare projects (Domingo, Osmani, & Price, 2008; 2009; Domingo, 2011), the assessment of sustainability issues and solutions for the existing healthcare facilities (Sheth, Price, Glass, & Achour, 2008; Sheth, Price, & Glass, 2010a; 2010b; 2010c; Sheth, 2011), and changes in hospital adaptation projects (Garthwaite & Eckert, 2012).

Since the focus of the journals of medicine is not particularly related to construction, the author of the thesis had to analyse carefully which recommendations concerned the improvement of management of refurbishment works in hospitals. The following guidelines were extracted from the work developed by Worley and Hohler (2008):

- Operating rooms renovation projects require planning and collaboration among physicians, hospital staff members, and vendors in order to ensure that all needs are met and any issues or concerns are addressed before construction begins (Worley & Hohler, 2008, pp. 917-919);

- The plan should include patient safety, as well as patient, physician, and staff flow. It must include infection control, safety guidelines, potential risk management issues, and adherence to all regulatory agency guidelines (Worley & Hohler, 2008, p. 923);
- Renovation projects also require a plan for completing demolition and construction without disrupting the daily functions of the operating room. This demolition plan may need to be broken into phases to maximize productivity. Demolition and construction of a centrally located area may require off-hours work to minimise noise and distraction to all involved. In addition, interim life safety measures must be in place and staff members educated on the guidelines[5] for safety and infection control for the construction project (Worley & Hohler, 2008, p. 923);
- A preconstruction risk assessment should be conducted after barrier walls are up to protect the working areas of the operating room (Worley & Hohler, 2008, p. 938);
- Daily inspections and meetings between the project director and contractor provide valuable oversight of the construction. Additionally, daily documentation must show that high-efficiency particulate air machines are running constantly and filters have been changed as required (Worley & Hohler, 2008, p. 938);
- During demolition, carry out daily checks to ensure that trash is being removed in covered bins, that the area is clean, that there are no water leaks, and that wet blankets or stick mats are strategically placed to contain dirt and dust (Worley & Hohler, 2008, p. 938);
- Throughout the construction process, daily inspections by infection control staff members, environmental engineers, and the project director or other designated personnel occur and are documented (Worley & Hohler, 2008, p. 938);
- Teams should include in the plans all areas that construction will affect, especially the areas adjoining the construction zone (Worley & Hohler, 2008, p. 938);
- Communication between team members can be facilitated throughout the planning, design, and building phases at regularly scheduled meetings. Communication tools can include minutes, a newsletter, updated memos, and bulletin boards designated for construction issues (Worley & Hohler, 2008, p. 939);
- As the construction project is completed, a checklist can ensure that everything is completed and in working order (Worley & Hohler, 2008, p. 941).

Guidelines related to the management of hospital refurbishments are also encountered in the study conducted by Ross et al. (2011). These are described as follows:

[5] In the original paper (Worley & Hohler, 2008), there is a table containing an extensive list of recommendations for safety and infection control for an operating room construction project. The topics covered by those guidelines range from dress code for surgical services during construction to required documentation at completion of the project, besides specific guidelines concerning noise and vibration control, security and safety procedure, etc.

- A multidisciplinary team should be established. It should perform risk assessment and determine necessary protective measures before starting any construction, renovation or maintenance work in health care settings (Ross et al., 2011, p. 1);
- In terms of protective measures, dust-protecting walls were installed insulating the ward from the affected construction areas (Figure 3 and Figure 4). Also, negative pressure was maintained in affected rooms during building activity and exhaust air was conducted outside through a sealed hole in the window (Figure 5) (Ross et al., 2011, p. 2);
- Patients with increased risk of invasive aspergillosis[6] should be identified and should be moved to other wards far away from construction and renovation areas and use of mobile HEPA (high-efficiency particulate air) filters should be considered (Ross et al., 2011, p. 6);
- Air pressure gradients are advised to be regularly verified in artificially ventilated areas (Ross et al., 2011, p. 6).

Figure 3 - Dust protection - view from a surgical ward (Ross et al., 2011)

Figure 4 - Dust protection - view from a renovation area (Ross et al., 2011)

[6] Aspergillosis is the name of a group of fungal conditions caused by a mould called aspergillus. It usually affects the respiratory system and causes wheezing and coughing, but it can spread to anywhere in the body. This information was extracted from NHS's website http://www.nhs.uk/conditions/Aspergillosis/Pages/Introduction.aspx

Figure 5 – Dust conducted outside through an HEPA filter (Ross et al., 2011)

Additional guidelines related to refurbishment of hospitals were also found in the research conducted by Lahtinen et al. (2009) as well as articles derived from case studies carried out in the construction industry (Constructing Excellence [CE], 2007; New Civil Engineer [NCE], 2013). A summary of these recommendations is presented as follows:

- Communication and cooperation between experts connected to the renovation and users of the building is necessary to succeed in the project (Lahtinen et al., 2009, p. 444);
- Noise, dust, and vibration must be kept to an absolute minimum due to potential adverse effects on patient recovery time (CE, 2007, p. 1);
- Construction must take place without disrupting patients' recovery and new and innovative solutions (Figure 6) have to be sought (CE, 2007, p. 2);
- Multiple solutions (e.g. fall back plans) have to be pre-planned to cope with the uncertainty inherent to refurbishment projects (NCE, 2013, p. 22).

Figure 6 - Deconstructive[7] acoustic screen used to shield the children's intensive care unit at The Royal London Hospital (CE, 2007)

[7] Deconstructive means that the acoustic screen can be dismantled and reused in other projects.

3.1.2.1.2.5 Retrofits

Retrofits, or sustainable retrofits, refer to the refurbishment of buildings with the purpose to improve their energy performance (Swan and Brown, 2013). This type of refurbishment has received great attention within the current research agenda due to its crucial role to meet sustainability targets (Itard and Meijer, 2008; Kelly, 2009; Mansfield, 2009; DBIS, 2010; DBIS, 2011; Mansfield, 2011, Swan & Brown, 2013, TSB, 2013, TSB, 2014).

Similarly to the broad area of refurbishment, there are few academic studies delving into how construction companies have been managing construction in retrofit projects. This is probably due to the numerous issues that exist around this subject such as policy and regulation, financial mechanisms, user engagement, energy consumption behaviour, renewable technologies, etc. This is particularly the case of large scale housing retrofit programmes[8] where a holistic or socio-technical perspective has been indicated by several authors as the appropriate way to address this theme in order to achieve better results (Wilkinson, 2012; Dixon & Eames, 2013; Swan, 2013).

Despite the lack of studies related to construction management, it is possible to identify recommendations for improvement in this regard. For example, Technology Strategy Board (TSB), the UK's innovation agency which is currently named as Innovate UK, funded a programme called Retrofit for the Future with the purpose to investigate how the existing homes can be improved to use less energy, cut carbon emissions, and save costs (TSB, 2014). Success factors to drive effective projects were compiled in two reports (TSB, 2013; 2014), which in total analysed the retrofit of 77 homes. A summary of these factors with an emphasis on aspects related to construction management is presented as follows:

Success factors presented in the first TSB's report (TSB, 2013, p. 25):

- Project planning
  - Time spent in detailed pre-design[9];
  - Researching the market for products and suppliers early on;
  - Detailed and realistic project planning, including extensive contingency planning and risk management;
  - Careful sequencing of works, enabled by well co-ordinated procurement.
- Site management
  - Dedicated co-ordination of the retrofit project;
  - Engaging and motivating the project team early on;
  - Open and frequent communication between project team members;

[8] For example, in the UK there is a need to address the refurbishment of the existing housing stock in order to meet the sustainable targets set by the government (DECC, 2008; Itard et al., 2008; Ravetz, 2008).
[9] Baker et al. (2013) provide an interesting discussion on the selection of domestic retrofit improvements.

- Understanding among the site staff of the importance of achieving good air-tightness.

- Understanding the supply chain
  - Building relationships with manufacturers;
  - Anticipating the availability, price, and lead time of innovative products;
  - Working with the suppliers of control systems to ensure that those installed are fit-for-purpose and simple to understand.

- Working closely with residents
  - Engaging residents early and frequently in the process;
  - Decanting residents;
  - Helping residents to understand how to manage their homes at different times of the year by explaining system controls;
  - Training support staff (call centre, maintenance) to provide informed, ongoing help to residents.

Success factors presented in the second TSB's report (TSB, 2014)[10]:

- Retrofit planning (TSB, 2014, p. 8)
  - Performance targets help unite project teams;
  - Retrofit must be tailored to specific, existing conditions of the house;
  - Detailed surveys, flexibility and contingency plans are all needed;
  - An initial meeting at the home helps design teams understand existing conditions, the overall strategy and the installation process;
  - Early engagement of residents helps in understanding their needs and managing their expectations;
  - Temporary services can be installed for people who stay at home during the works;
  - Early talks with suppliers can ensure that products and services are chosen according to the suppliers' capabilities;
  - Early engagement with local planners reduces the risk that proposed solutions may not be approved;
  - Items made off site (e.g. modular heating pods, pre-fabricated roofs) can be easier to install on site.

- Working on site (TSB, 2014, p. 34)
  - Effective and informed project management and coordination;
  - Continued involvement of the design team once on site;
  - Briefings to help teams to understand and commit to the retrofit aims;

[10] It should be noted that this second TSB's report (TSB, 2014) presents also recommendations on other important retrofit areas such as building fabric, indoor air quality, and services. However, as noted earlier in this section, the intention is to emphasize aspects more related to construction management since this is the focus of this thesis.

- Site operatives should watch airtightness tests to see the results of their work;
- Whichever supply chain model is chosen, clear responsibilities and communication are critical;
- A realistic timetable with a logical sequence of works, well-structured contracts and clear expectations on the supply chain can mitigate delays.

- Engaging residents (TSB, 2014, p. 40)
  - Continual engagement with residents during the project;
  - Tours of the house while work is under way;
  - If there are delays or additional works, give residents time to reflect and adapt to them;
  - A handover should cover all elements of the retrofit, but with particular attention to the different systems and how use them together as one system;
  - Provide user-friendly controls and clear guidance;
  - Aftercare visits to make sure people are comfortable and are using systems well;
  - Visit again when new residents move in.

Guidelines on how to improve performance of retrofit projects are also found in the FutureFit study (FutureFit, 2011; Willey, 2013) carried out by the housing association Affinity Sutton in partnership with the Energy Saving Trust, a social enterprise[11] with a charitable Foundation, and the project developer Camco. The programme involved the retrofit of 102 properties owned by Affinity Sutton and addressed different issues with regard to the retrofit delivery. Lessons learned from the installation phase of the project are listed as follows:

- Work packages need to be tailored for each property to take into account the property attributes, condition, and resident needs (FutureFit, 2011, p. 3);
- Although none of the technical issues are insurmountable, consideration needs to be given to aligning the work programme to trigger points[12] to keep both costs and disruption to a minimum. Certain property types are intrinsically less suited to specific measures and in this case due consideration should be given to the cost-benefit of alternative options/specifications (FutureFit, 2011, p. 3);
- The potential to bring retrofit costs down needs to be assessed by engaging with the supply chain and integrating work packages more closely with maintenance regime and overall asset management programme (FutureFit, 2011, p. 3);

---

[11] Social enterprises are businesses that reinvest or donate profit to create positive social and/or environmental change. For further information on this topic please go to https://www.socialenterprise.org.uk/What-is-it-all-about

[12] According to Energy Saving Trust, trigger points refer to "*a logical, effective, and affordable approach to sustainable retrofit*". The basic idea is to consider the possibility to stretch the scope of the refurbishment in order to bring down the marginal cost of installing the work packages. For further information on this subject please go to http://www.energysavingtrust.org.uk/Organisations/Technology/Technical-resources/Trigger-points

- The role of the resident liaison officers (RLOs) was key in explaining the project and its implications. They needed to be on hand during the works to resolve any issues and maintain resident engagement in the scheme (Willey, 2013, p. 134);
- The delivery teams felt that resident engagement needed to go beyond getting a 'yes' to the works; residents needed to fully understand the installation process and the implications of adapting packages of works (Willey, 2013, p. 134); and
- For these works to have their desired impact and to ensure a smooth process, FutureFit findings suggest that the entire delivery team – including contractors, surveyors, and RLOs – need training. This will make sure that the same message and levels of understanding are passed on to residents (Willey, 2013, p. 136).

3.1.2.1.3 Summary

A critical analysis of the guidelines found in the literature revealed interesting patterns in terms of suggestions for a better project management. The numerous prescriptions made by several authors to address distinct refurbishment contexts can be summarised into six categories as follows:

- Foster collaboration, engagement, and early involvement;
- Safeguard users and operations in the existing building;
- Reduce uncertainty;
- Use appropriate contract strategies, procurement routes, and management systems;
- Provide contingencies; and
- Work with skilled people in refurbishment projects.

Next, a brief explanation of each category is provided along with examples extracted from the literature. The full list of guidelines as per the categories mentioned above is presented in Appendix 1.

3.1.2.1.3.1 Foster collaboration, engagement, and early involvement

This kind of recommendation is the most common instruction noted in the literature. It can be found in all types of guidelines cited in the review. Out of 129 guidelines assessed, 47 are classified under this category. The following examples demonstrate the typical content of such guidelines:

> "Promote close collaboration between the parties, i.e., client, contractors, designers, building managers, etc., and identify decision makers and their areas of responsibility" (CIRIA, 1994).

> "Select the project team early (Egbu, 1997; Mitropoulos and Howell, 2002). Encourage early involvement of the construction team with the design" (CIRIA, 1994).

> "Involve builders as early as possible to avoid problems later" (CIRIA, 2004, p. 34).

> "Communication and cooperation between experts connected to the renovation and users of the building is necessary to succeed in the project" (Lahtinen et al., 2009, p. 444).

> "Early talks with suppliers can ensure that products and services are chosen according to the suppliers' capabilities" (TSB, 2014, p. 8).

3.1.2.1.3.2 Safeguard users and operations in the existing building

This type of guideline is the second most common instruction observed in the literature. In total, there are 43 examples of this kind out of 129 recommendations listed in the review. This guideline is found mainly in the sections named "refurbishment of occupied buildings" and "refurbishment of hospitals". The following prescriptions illustrate the usual message conveyed by this kind of recommendation.

> "Provide assistance to users in managing disruptions" (CIRIA, 1994).

> "The programme for refurbishment should be coordinated with occupants' activities. Effective time management can reduce conflicts between occupants and builders." (CIRIA, 2004, p. 33).

> "Construction must take place without disrupting patients' recovery and new and innovative solutions have to be sought" (CE, 2007, p. 2).

> "Items made off site (e.g. modular heating pods, pre-fabricated roofs) can be easier to install on site" (TSB, 2014, p. 8).

3.1.2.1.3.3 Reduce uncertainty

There are 17 recommendations on this respect out of 129 listed in the literature review. The section on "general guidelines" presents the high number of this type of prescription followed by the section on "retrofits". The development of a thorough building survey in the existing asset is the most common recommendation on this regard. The anticipation of project constraints, the use of prototyping, and the development of pre-design are also classed under this category as they align with the purpose of reducing uncertainty. Examples of this type of guideline are provided as follows:

> "Conduct extensive investigation work on the existing building" (CIRIA, 1994).

> "Accelerate the discovery of the existing conditions and constraints" (Mitropoulos and Howell, 2002).

> "Carry out surveys to identify the presence of materials that may be hazardous" (CIRIA, 2004, p. 71).

> "Prior to undertaking any demolition activity on site that may interfere with the structural stability of the building, preliminary surveys and site investigations have to

be carried out by structural engineers as well as specialist demolition contractors" (Anumba et al., 2004, p. 9).

3.1.2.1.3.4 Use appropriate contract strategies, procurement routes, and management systems

Ten guidelines are classified under this category. The basic purpose of this recommendation is to ensure the use of management systems, contract strategies, and procurement routes compatible to the nature of refurbishments. It also aims at fostering collaboration among stakeholders. Examples of this kind of guideline are described as follows:

> "Set up a management system and contractual procedures compatible with project objectives. Make sure they are sufficiently flexible to be able to cope with changes" (CIRIA, 1994; Egbu, 1997).
>
> "The client should choose a procurement route compatible with their objectives for the refurbishment and the nature of the project" (CIRIA, 2004, p. 21).
>
> "The form of contract is critical in establishing cooperation and avoiding confrontation" (CIRIA, 2004, p. 31).

3.1.2.1.3.5 Provide contingencies

Despite the few number of recommendations on this regard, only nine out of 129 guidelines listed in total, it is noteworthy that this kind of prescription was made for all refurbishment types addressed in the literature review (except refurbishments involving demolition and structural instability). The provision of contingencies refers basically to the development of "what-if" scenarios, fall back plans, and allocation of time and money for dealing with unforeseen situations. Examples of these guidelines are provided as follows:

> "Provide realistic contingencies in plans, programme and resources, including options and fall-back positions" (CIRIA, 1994, p. 31).
>
> "Develop "what if?" scenarios in advance" (CIRIA, 2004, p. 49).
>
> "Multiple solutions (e.g. fall back plans) have to be pre-planned to cope with the uncertainty inherent to refurbishment projects" (NCE, 2013, p. 22).

3.1.2.1.3.6 Work with skilled people in refurbishment projects

There are only three guidelines classed under this category. They are found in the sections on "general guidelines", "refurbishment of occupied buildings", and "refurbishment involving demolition and structural instability". These are presented as follows:

> "Work with experienced people who have a good track record on refurbishment projects, e.g., a specialist contractor" (CIRIA, 1994; Krizek et al., 1996).

> "Make sure that the firms and individuals have the capability to deliver" (CIRIA, 2004, p. 46).
>
> "Refurbishment projects involving demolition activities require the appointment of competent and qualified professionals who are going to implement health and safety in the development of any stage of the project, from design to execution phase" (Anumba et al., 2004, p. 9).

In addition to the guidelines aforementioned, there are also other types of artefacts devised with the purpose to improve the management of refurbishment projects. These are addressed in the following section.

3.1.2.2 Other types of artefacts

In this section, the alternative artefacts devised to tackle specific issues related to management of refurbishment projects are presented. Similarly to the previous section, the selection of studies presented here is based on their connection to the topic investigated in this study. Yet, it is worth mentioning that in this thesis, the intention is not to delve into details about those artefacts, since further information can be found in the original publications. The main purpose here is to show artefacts different from the usual guidelines presented previously, as well as making the due considerations regarding their applicability in refurbishment projects.

Whiteman and Irwig (1988) developed a modified version of the Critical Path Method (CPM) called Disturbance Scheduling Technique. The artefact was devised with the purpose to improve workflow in renovation projects by integrating, via an algorithm, construction activities with building operations. However, it is a CPM-based technique, which means that it follows the rationale of traditional CPM, hence presenting the same shortcomings of CPM noted earlier. Thus, it is argued that such a technique is not suitable for dealing with the complex and uncertain project contexts such as the ones found in refurbishment projects.

Singh (2007) developed a framework for production management of refurbishment projects with the purpose of improving the schedule performance. The artefact is based on methods to calculate the impacts of constraints (Table 6) on the duration of activities defined by the researcher as critical in renovation projects. These activities include: preparation of plans and specifications, site investigation by contractor, preparation of site logistics plan, mobilization and demobilization, temporary construction, selective demolition, material and equipment procurement, demolition waste management, and MEP rough-ins[13].

[13] Rough-in means to lay out the basic lines without making the final connections. For example, an electrical rough-in job would mean to pull all of the electrical cables through the studs and into the boxes, but light switches, outlets, lights and other devices would not be attached (Source: https://www.thespruce.com/what-does-rough-in-mean-1821746). It is noteworthy that rough-in is a term often heard in North America. In the UK, the term 'first fix' is more commonly used (Source: https://en.wikipedia.org/wiki/First_fix_and_second_fix).

The research carried out by Singh (2007) is important because it recognises the complex nature of refurbishments and shows the impact it can have on project schedule. Nevertheless, two main issues are observed in the study. Firstly, the framework was not applied in a real project, but it was only assessed via a hypothetical test and interviews. This fact limited the assessment on the practical utility of the artefact. Secondly, the artefact seems difficult to use due to the numerous steps required for its application. Perhaps, an improved version of the framework can overcome this barrier.

Table 6 - Constraints and project conditions for renovation projects (Singh, 2007)

Constraints	Project Conditions
Utility Constraint	Limited capacity of downstream system
	Non-disruption to existing utilities
	Impact of existing utilities and/or structural systems on the design of new systems
Physical Constraint	Space limitations for construction
	Space limitation for material storage
	Space limitation for installing new equipment / material
Pollution Constraint	Noise Control
	Dust Control
	Debris Control
	Vibration Control
	Odour Control
Uncertainty Constraint	Non-availability of as-built drawings
	Presence of unforeseen conditions
	Presence of hazardous material
Coordination Constraint	Timing limitations due to owner operations
	Relocation of owner operations to and from swing space
	Owner furnished equipment
	Removal and reinstallation of owner’s furniture
	Multiple inspections by end-users and owner’s representatives
Regulatory Constraint	Non-conformance of existing materials or project conditions with current codes
Traffic Constraint	Limitations of materials and equipment movement
Schedule Constraint	Additional duration due to work restructuring
	Impact on crew productivities
Safety Constraint	User and public safety

Ho (2009) addresses the issues related to renovations of occupied buildings by devising an automated method to identify occupant interactions. It aims at formalising and integrating the necessary renovation planning information (organisational, spatial, and temporal) to enable a comprehensive and detailed identification of occupant interactions. To this end, the artefact was first implemented in a computer prototype and then a prospective validation was conducted in three building renovations. It proved to be effective as improvements in the original production plans were achieved based on the analysis made by the artefact. Also, it increased transparency by improving the visualisation of occupant locations and improved planning accuracy by automating the integration of the required information (tenant, schedule, and spatial information) to coordinate the moves in the building.

Despite being limited to a specific issue (i.e. identification of occupant interactions), the method devised by Ho (2009) can be useful to assist managers in the execution of the planning tasks in the refurbishment of occupied buildings. However, it is noteworthy that there are other issues related to construction management that should not be forgotten. This refers to, for example, the due consideration of project constraints (e.g. materials, workforce, equipment, information, access, etc.) during planning stage.

Another artefact proposed to improve the performance of construction projects, including refurbishments, is the Front End Planning (FEP) devised by the Construction Industry Institute (CII) in the United States (CII, 2009; Howard et al., 2009; Whittington et al., 2009). The FEP is defined by the CII as "the process of developing sufficient strategic information with which owners can address risk and decide to commit resources to maximise the chance for a successful project" (CII, 1994, cited in Howard et al., 2009, p.2).

Basically, the underlying idea of FEP is the correlation between the level of pre-project planning effort and project success. In other words, it means that a well-defined scope, achieved by an appropriate pre-project planning or FEP, leads to enhanced project performance. A tool called Project Definition Rating Index (PDRI) measures the level of completeness of project scope definition. The FEP process is presented in Figure 7.

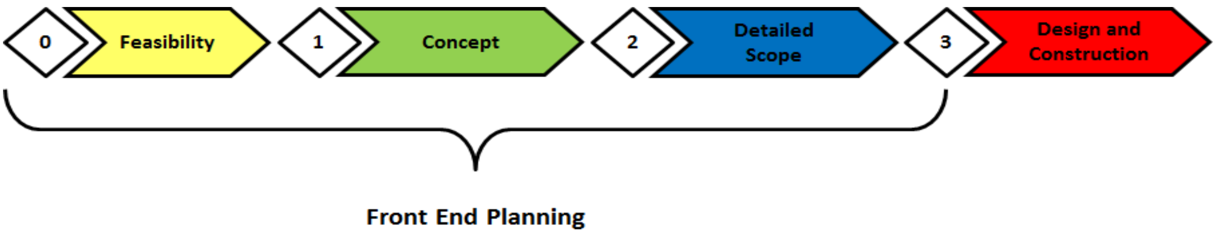

Figure 7 - Front End Planning (CII, 2009)

In terms of the applicability of FEP for refurbishment projects, the research developed by Howard et al. (2009) indicates that it can add value to these projects, but the process should be tailored for the particular case of refurbishments. In this respect, the research team, based on the intrinsic risks related to refurbishments, identified several critical activities worth to be addressed during FEP on this specific project setting (CII, 2009, p. 9).

- Ensure alignment and conduct teambuilding;
- Choose contract strategy for project constraints;
- Define existing conditions;
- Identify and engage key stakeholders;

- Follow a defined front end planning process;
- Define critical scope issues;
- Ensure labour and material availability;
- Explore alternative construction methods;
- Apply leadership and experience.

Despite playing an important role on risk mitigation, the FEP acts predominantly on the strategic level, therefore not looking directly at how operations on site should be managed. The FEP process depicted in Figure 7 is a clear indication of that. Consequently, further research is necessary to fill the gap existing in the operational sphere.

Finally, it should be acknowledged here the existence of studies (e.g. Ballard, 2000; Horman, Messner, Riley, & Pulaski, 2003; Tuholski, Gursel, Tommelein, & Bomba, 2009; Pereira & Cachadinha, 2011; Bryde & Schulmeister, 2012; Ladhad & Parrish, 2013), in which the utility of well-known artefacts (e.g. Last Planner System) in refurbishment projects is assessed. These studies are addressed afterwards due to the fact that they all present some sort of connection to the theory of production that is presented in the next section. It would make no sense to address them here, without mentioning their theoretical background, as it would be pointless to make references to a theory without introducing it properly. Thus, for the sake of coherence, the author decided to defer the analysis of those studies.

3.1.2.3 Discussion

Undoubtedly, the guidelines found in the literature provide useful information on issues concerning the management of refurbishment works. Six categories of recommendations were found on this regard. However, there are some aspects not addressed by those who devised those guidelines. The missing points are outlined below.

Firstly, guidelines provide an indication on what should be done in order to be successful, but it is rarely explained how those instructions can be operationalized in a real project. In other words, it is uncommon to find a suggestion of managerial methods that could be adopted to support the implementation of such recommendations.

Secondly, there is a lack of evidence on the implementation of guidelines in real projects. It would be interesting to assess the practical contribution of such recommendations. It is argued that field tests would provide insights on the enablers and barriers to implement the guidelines and would also serve to verify their impact on project performance.

Thirdly, the guidelines found in the literature are not grounded on scientific knowledge, but only practice-based. Normally those recommendations are based on interviews with skilled project managers or practical lessons extracted from case studies. While this expertise is welcome, it is argued that it should be backed up by a sound theoretical foundation. The importance of having a proper theory to inform management decisions is clarified in the second part of the literature review.

Finally, regarding the other type of artefacts devised for improving the management of refurbishment projects, it is argued that they all present particular problems which limit their effectiveness for enhancing performance of production in refurbishment sites. Therefore, they are not adequate for attaining the aim set for this study.

3.1.3 Conclusions

The literature review has provided valuable information on which directions this research should take in order to achieve its objectives. The main insights are presented below.

Firstly, refurbishments present unique features that should be taken into account if one wants to improve the management of construction in this particular setting. The existing asset and the operations in the existing building are the most distinguishable characteristics of refurbishments. These particular features influence the management of construction since they tend to increase the complexity of the project.

Secondly, the underlying reason behind the failure of the construction management approach traditionally applied in refurbishment projects is the theoretical foundation on which typical managerial practices are grounded, namely, the transformation view of production. It is argued that it is not sufficient to cope with the complexity and uncertainty intrinsic to refurbishments. This fact underlines the importance of having a sound theory of production as the reference basis upon which the managerial solutions proposed in this thesis should be underpinned. It is noteworthy that theory of production is a topic normally ignored by authors who carry out research on construction management in refurbishment projects.

Thirdly, guidelines are instrumental in pointing out what should be done for improving project management, but whenever possible they should come along with an indication of methods or tools for supporting their practical use. These, in turn, should be tested preferably in a real project to assess their practical utility as well as to examine the implementation issues. Finally, both guidelines and managerial methods should be grounded on a sound theoretical background, to ensure they are effective in producing improvements on refurbishment sites.

The combination of the aforementioned arguments shaped the content of the following section. Next, topics such as management of complex and uncertain projects, theory of production, and managerial methods for construction management are addressed. Altogether, these subjects will serve as ingredients to the creation of the main artefact proposed in this thesis, i.e. method for construction management in refurbishment projects.

3.2 Towards an appropriate construction management approach in refurbishment projects

In the first part of the literature review, it was argued that it is primary to understand the project context in order to select an appropriate construction management approach. It was also contended that refurbishments are more complex to manage than new build projects due to their particular nature. These arguments outline the subjects addressed in the initial part of this section such as project complexity and the approaches for managing it properly.

The second part of this section addresses another issue reported previously, i.e. the need of a sound theoretical foundation to serve as a reference basis for better project management. To this end, the theory of production upon which the solutions proposed in this thesis are underpinned is presented along with evidences of its practical implementation in refurbishment projects. Yet, managerial methods based on such theory are presented as candidate solutions for improving construction management in those projects.

3.2.1 On project complexity

There is a consensus in the literature that construction projects have become more complex over time (Shenhar & Laufer, 1995; Baccarini, 1996; Gidado, 1996; Williams, 1999). The same authors argue on the need of devising appropriate management systems to cope with such project complexity. Indeed, as shown earlier in this thesis, the adoption of incompatible management practices is likely to lead to poor project results.

In this section, the sources of complexity in construction projects in general, as well as refurbishments are revealed. In addition, the management approaches recommended in the literature to deal with complex projects are presented.

3.2.1.1 Refurbishments as complex projects

Baccarini (1996) argues that project complexity consists of "many varied interrelated parts" and that it can be operationalized in terms of differentiation, which means the number of the diverse elements (i.e. tasks, specialists, and components), and interdependence, meaning "the degree of interrelatedness between these elements" (Baccarini, 1996, p.202).

Williams (1999; 2002) considers those elements cited by Baccarini (1996) as Structural Complexity since they refer to the underlying structure of the project. He brings also an additional element to the idea of complexity: uncertainty, which can be understood in terms of goals and methods. He argues that both concepts (structural complexity and uncertainty) produce together "the difficultness and messiness of the overall project" (Williams, 1999, p. 271). Those dimensions of project complexity are shown in Figure 8.

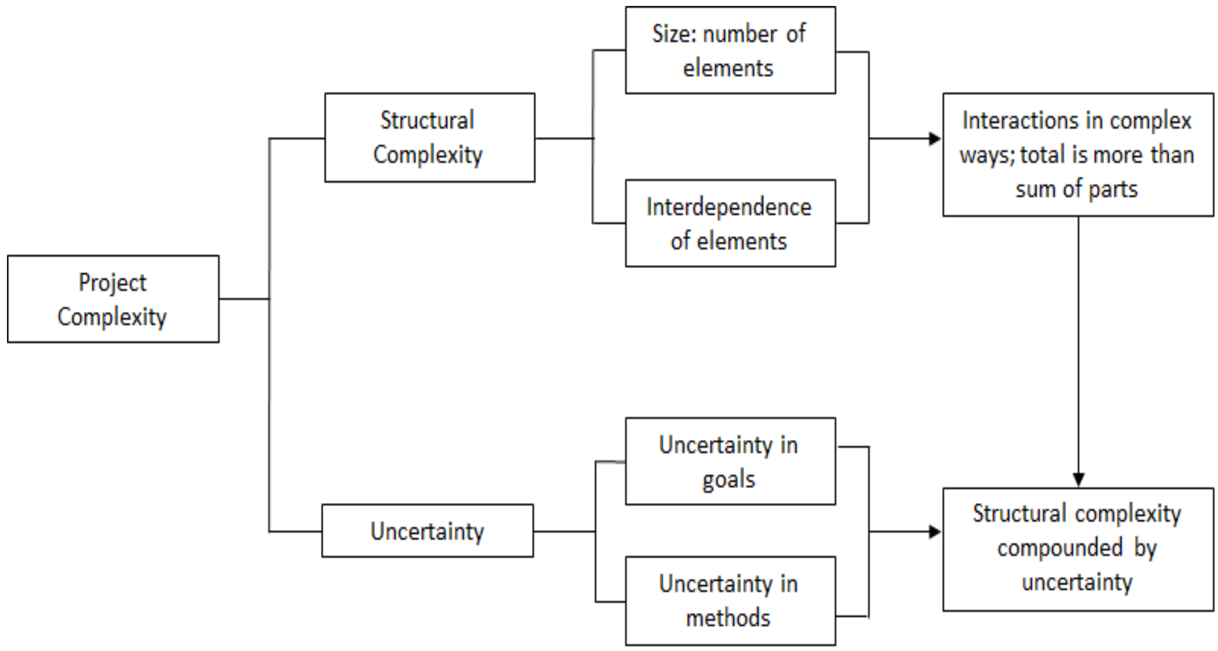

Figure 8 - Dimensions of project complexity (Williams, 2002)

Interdependence and uncertainty have been recognised as key features in construction for a long time (Crichton, 1966). Gidado (1996) argues that the construction process is characterised by a high number of interconnected parts. He also considers uncertainty as a component of project complexity that can be related to the following aspects (Gidado, 1996, p. 216):

- Lack of complete specification for the activities to be executed;
- Unfamiliarity of the inputs and/or environment by management;
- Lack of uniformity of work;
- Unpredictability of the environment (e.g. refurbishment of very old buildings having no as-built drawings).

Interestingly, the definitions of complexity encountered in the literature are similar to the perceptions of people in industry. Gidado (1996) carried out interviews with construction practitioners and found out that they view a complex project as follows:

- A project having a large number of different systems that need to be put together and/or with a significant number of interfaces between elements;
- A project involving works in a confined site with access difficulty and requiring many trades to work in close proximity and at the same time;
- A project with a considerable degree of intricacy which is difficult to specify clearly how to achieve a desired goal or how long it would take;
- A project which demands a great number of details on how it should be executed;
- A project that requires efficient coordination, control, and monitoring from start to finish.

According to Koskela (2000), the peculiarities of the construction sector such as one-of-a-kind nature of projects, site production, and temporary organisation, contribute to added complexity and uncertainty to production. Bertelsen (2003a; 2003b) and Bertelsen and Emmitt (2005) contend that complexity in construction projects stems from several sources such as the design process, the project organisational structure (i.e. several stakeholders with different objectives each one), the operations on site (i.e. parallelism), the client's often irrational behaviour, the weather, etc. Those characteristics show that construction projects are generally complex by nature.

The complexity and uncertainty in refurbishments is often higher than what is found in new build projects. According to Noori et al. (2016), this is caused by several factors such as unforeseen site conditions, site access, lack of space, availability of material, design change, defective design and plan, and lack of information during the design phase. Indeed, as showed previously in Table 3, the typical features of refurbishments (e.g. lack of as-built drawings on the existing asset, interference with building occupation and operation, short construction timeframes, etc.) tend to increase the complexity in comparison to new build projects, hence producing particular management challenges. It is therefore reasonable to conclude that refurbishments are complex projects.

The acknowledgment of refurbishments as complex projects has important implications from a project management standpoint. Baccarini (1996, p. 201) emphasises it by outlining the following reasons:

- Project complexity helps determine planning, coordination, and control requirements;
- Project complexity hinders the clear identification of goals and objectives of major projects;
- Complexity is an important criteria in the selection of an appropriate project organisational form;
- Project complexity influences the selection of project inputs, e.g. the expertise and experience requirements of management personnel;
- Complexity is frequently used as criteria in the selection of a suitable project procurement arrangement;
- Complexity affects the project objectives of time, cost, and quality. Broadly, the higher the project complexity the greater the time and cost.

Gidado (1996) contends that project complexity has been associated to the difficulty of implementing a planned production workflow. He also recognises the relationship between management systems and project complexity as can be seen in the following quote: "an efficient implementation of managerial functions (planning to controlling) can influence the effect of project complexity on project success" (Gidado, 1996, p. 218).

Bertelsen and Koskela (2003) recommend the use of a complexity approach for improving the understanding of construction processes. Bertelsen (2003a; 2003b) argues that acknowledging construction projects as complex settings leads to a new way of managing projects, which is quite different from the traditional project management approach. In conclusion, as stated by Bertelsen and Koskela (2005, p. 70) "the complex and often turbulent world of project production should take the project complexity and dynamics as an outset and design and operate its management systems from that perspective".

3.2.1.2 On the management of complex and uncertain projects

As underlined in the previous section, understanding construction projects as a complex phenomenon leads to particular ways of management. Several authors have proposed a number of approaches to deal with the complexity and uncertainty inherent to construction.

Laufer (1991) investigates the consequences of project uncertainty on construction planning and proposes an approach[14] to cope with it. It includes an early and systematic diagnostic phase followed by three measures. The former is concerned to an overall assessment of the project environment, which includes an analysis regarding technological and organizational aspects, and the latter is described as follows (Laufer, 1991, p. 58):

- Narrowing down uncertainty by gathering more information;
- Adjusting to uncertainty by deferring and splitting decisions as much as possible, thus gaining more complete or stable information;
- Absorbing uncertainty when postponement is no longer possible by making flexible, robust, and less sensitive decisions (this solution might at times be sought before deferring decisions).

Howell, Laufer, & Ballard (1993) recognise the uncertain nature related to the process of setting project objectives and provide recommendations on how to deal with this phenomenon. The main message put forward by those authors, is to avoid the assumption that objectives must be completely fixed at the outset, because this notion does not match to the environment in which projects normally take place. Thus, they suggest a more flexible approach, in which the objectives and their supporting premises are tested and refined gradually by taking into consideration the information available at the time (e.g. constraints related to the means to achieve objectives).

Baccarini (1996) points out integration as a way to deal with this complex scenario. This refers to the prioritisation of aspects such as coordination, communication, and control. Following the same line of thought, Laufer et al. (1996) also recommend a project management style based on elements such as integration, systemic management, and

[14] The approach devised by Laufer (1991) is focused "primarily on management's ability to make effective decisions during project planning, that is after the decisions have been made concerning construction technology, organizational structure, and contractual strategy".

mainly simultaneous management. These researchers summarised this management style in a list of principles divided in three groups (Table 7).

Table 7 - List of principles for simultaneous management (Laufer et al., 1996)

Groups	Principles
Planning	Systematic and integrative planning
	Plan systematically and integratively. Start as early as possible, set project objectives and employ a multi-stage process. At each stage prepare all functional plans simultaneously and interdependently.
	Timely decisions adjusted to uncertainty
	Adjust the timing of decisions and their degree of completeness, the planning horizon and the degree of detail of the plan to the completeness and stability of information. Selectively split decisions to enhance their stability. Accelerate their implementation to obtain fast feedback for further planning.
	Isolation and absorption
	Decouple interdependent tasks and isolate tasks plagued by very high uncertainty. When decoupling is impossible, absorb the uncertainty by employing redundant resources selectively, or manage the interface between interdependent tasks.
Leadership and integration	Inward and outward leadership
	The project manager should lead the project throughout. To do so, he or she must assume both internal and external leadership roles.
	Multi-phase integration
	Involve the leaderships of the next phases of the project in planning as early as possible. When conditions permit proceed to execution overlap.
	Multi-disciplinary teams
	Develop multi-disciplinary teams at the various levels. Involve all concerned parties and foster cooperation and teamwork.
Systems	Intensive communication
	Design and foster intensive, open and timely communication within and without teams. Employ multiple channels and mediums, in particular modern information technology and extensive face-to-face interactions.
	Simple procedures
	Prepare systems that prescribe for most processes simple and brief procedures. All flexibility of detail in 'how to'. Restrict optimization to the essential.
	Systematic monitoring
	Systematically monitor project performance of achieving objectives and utilization of means. Periodically scan the project environment and monitor the changes in the critical planning assumptions.

As a criticism to the traditional management-as-planning[15] style, Bertelsen (2003a) proposes the use of supplementary approaches for organising, planning, and controlling the construction process. This involves, for instance, the consideration of other elements to improve project management such as self-organisation and cooperation.

Bertelsen and Koskela (2003) argue that it is important to understand the project environment and propose an assessment based on the analysis of four characteristics,

[15] In simple terms, the management-as-planning approach assumes that the project can be considered as an ordered phenomenon, thus susceptible to be represented and manipulated by plans. A more thorough explanation on this subject can be found in study developed by Johnston and Brennan (1996).

namely, project complexity, project's internal and external setting, and project organisation. The underlying idea of this exercise is to increase awareness of participants regarding the nature of the project in order to enable discussions and actions to support the management of complexity. In a subsequent paper, Bertelsen and Koskela (2005) support the aforesaid idea by stating that improvements in productivity in complex and uncertain projects emerge through a better knowledge of the project situation, but they should also come from the development of methods suitable to handle uncertainty (e.g. Last Planner System). They also propose the following strategies for managing complexity.

- Build in buffers (slack, margin) for absorbing the impacts of complexity;
- Reduce the complexity or dynamics seen from an operational point of view;
- Codify the procedures to be used and train in performing these procedures under stress;
- Improve the system's own capability to act on the given situation without orders from the management.

Saurin, Rooke, & Koskela (2013) and Saurin et al. (2013) have also devised guidelines for the management of complex social-technical systems based on a thorough literature review of studies related to complex systems theory. These include:

- Give visibility to processes and outcomes;
- Encourage diversity of perspectives when making decisions;
- Anticipate and monitor the impact of small changes;
- Design slack;
- Monitor and understand the gap between prescription and practice;
- Create an environment that supports resilience.

In summary, the views on complexity provide the basis for understanding refurbishments as complex projects as well as the practical implications of such interpretation. Attributes such as number of elements in a project (e.g. tasks, specialists, components), interdependence between those elements, and uncertainty should be taken into account when defining the management approach to be adopted in a project. This would avoid poor decisions in terms of project management such as using highly detailed CPM schedules to coordinate complex and uncertain projects. Also, as often those attributes cannot be eliminated, they must be recognised and mitigated through the use of appropriate managerial practices. For instance, the planning approach should be designed to handle the uncertainty and variability inherent to construction and be based on elements that are helpful in supporting the management of complexity such as cooperation, coordination, integration, self-organisation, communication, etc. Therefore, it is argued that the acknowledgement of complexity in construction projects is essential for the selection of a management approach.

As important as understanding the complex nature of refurbishment projects, is the need of a sound theoretical foundation as a reference basis for an effective production management.

Next, the importance of a theory of production is clarified. Also, the theory selected in this research to provide guidance on the management of refurbishment works is presented.

3.2.2 Theory of production in construction

Earlier in this thesis, it was contended that a sound theory of production is required for underpinning an effective construction management. Thus, the indication of such theory is primary. This section starts by stressing the importance of a theory of production. Then, the theory selected as a reference basis in this research as well as evidence of its practical implementation in refurbishment projects are presented. Managerial tools and techniques are proposed as candidate solutions for improving the management of refurbishments.

3.2.2.1 Why is a theory of production necessary?

According to Koskela (2000), a theory of production shares the same purposes with the theories in general. These functions are summarised as follow (Koskela, 2000, pp. 25-26):

- Explanation - a theory provides an explanation of observed behaviour, and contributes thus to understanding;
- Prediction - a theory provides a prediction of future behaviour; in the case of production, especially of the contribution of action to goals;
- Direction – a theory pinpoints the sources of further progress;
- Testing – when explicit, it is possible to constantly test the theory to prove its validity.

However, differently from natural and behavioural sciences, in the case of production management a theory has also other functions (Koskela, 2000, p. 26). These are presented as follows:

- Tools for decision and control – on the basis of a theory, tools for analysing, designing, and controlling production can be built (Kochikar & Narendran, 1994);
- Communication – a theory, when shared, provides a common language or framework, through which the co-operation of people in collective undertakings, like a project, firm, etc., is facilitated an enabled (Heim & Compton, 1992);
- Learning – a theory can be seen as a condensed piece of knowledge: it empowers novices to do things that formerly only experts could do (Fenves, 1996);
- Transfer – innovative practices can be transferred to other settings by first abstracting a theory from that practice and then applying it in target condition (Lillrank, 1995).

Finally, as stated by Koskela (2000), from the perspective of practice of production management, the application of the theory should lead to improved performance, as well as the lack of it, should culminate in inferior performance. According to the same author, this argument illustrates the power and significance of a theory from practical point of view: "it provides a direct benchmark for practice" (Koskela, 2000, p. 34).

3.2.2.2 *On the existing theories of production*

Koskela (2000) carried out an investigation on the existing theories of production. He found out three main approaches proposed throughout the 20th century, namely, the Walrasian production model, the Factory Physics model, and the product realisation model. An overview of these theoretical approaches to production is presented in Table 8.

Clearly, the proposed theories address different issues related to production. As noted by Koskela (2000), these propositions differ not only in terms of principles for management of production, but they also diverge with regards to the basic nature of production, namely, while one conceptualise production as transformation, the others deemed it as flow or value generation. None of these proposed theoretical approaches alone seems suitable for fulfilling the needs of a sound theory of production (Koskela, 2000).

Table 8 - Overview of proposed theories of production (Koskela, 2000)

	Walrasian production model	**Factory Physics model**	**Product realisation model**
Motivation	Fragmentation of the existing theory	Deficiencies of existing production control practices	Deficiencies of the functional organisation
Strategy of theory formation	Unification of earlier developments in the analysis of production systems	Mathematical modelling by means of queueing theory	Generalisation of Taguchi's theory of quality and unification with earlier developments from microeconomics and marketing
Domain	Production, engineering	Manufacturing, especially of "disconnected flow line" type	Product realisation process (entire design and manufacturing process)
Conceptualisation of production	Transformation	Flow	Provision of total quality (defined as net value of a product to the society)
Goals addressed	Not explicit	Costs, sales	Value-to-the-customer, cost, pace of innovation
Major principles	Decomposition of products and resources	Variability reduction, control strategies	Quality loss reduction
Validity	Illustrative examples of application	Illustrative examples of application	Illustrative examples of application

However, these three major views on production served as the starting point for the formulation of a sound theory of production developed. In order to integrate these different views, Koskela (2000) proposed that production could be conceptualised by using these three perspectives simultaneously: transformation (T), flow (F), and value (V), thus giving rise to the TFV theory of production. Next, further details on this theory are presented.

3.2.2.3 *TFV theory of production*

The TFV theory of production came up as a successful endeavour to integrate the transformation, flow, and value concepts. The features of this integrated view on production are summarised in Table 9.

Historically, the transformation theory has been the dominant view applied in practice (Koskela, 2000). According to this theoretical view, a production process is understood as a transformation of inputs into outputs (Figure 9). The principles that underpin this conceptual view of production include, for example, the decomposition of the transformation process into subprocesses (which are also transformation processes) and the minimization of total cost trough the reduction of cost of each subprocess.

Table 9 - Integrated TFV view on production (Koskela, 2000)

	Transformation view	Flow view	Value generation view
Conceptualisation 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 realised 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, Organisational 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

While the transformation view is helpful for specific purposes (e.g. determining which tasks are needed in a project), it fails to recognise the existence of other activities (Figure 10) in production (non-value-adding activities such as moving, waiting, and inspection) as well as acknowledging that value in production is having the output conform to the customer's requirements and not by just transforming input into outputs (Koskela, 2000).

Figure 9 - Transformation model (Koskela, 2000)

The flow concept of production emerged as a criticism to the transformation view. According to Shingo (1988), production is a network of operations and processes (Figure 11) and for that reason there must be a clear distinction between those two phenomena, namely, the former refers to "the discrete stage at which a worker may work on different products" and the latter refers to "the flow of products from one worker to another" (Shingo, 1988, p. 5).

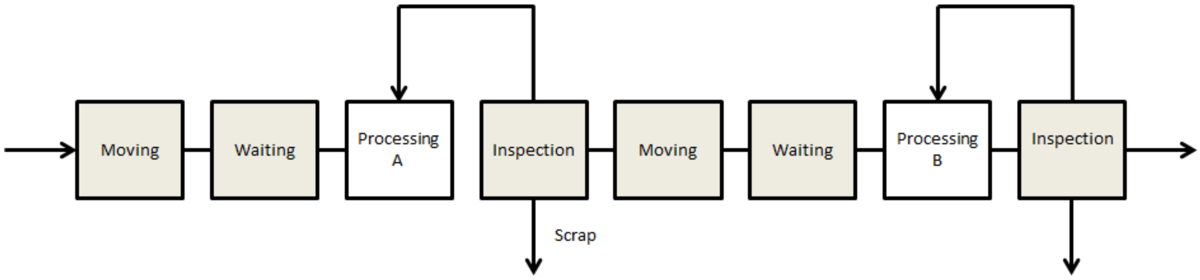

Figure 10 - Production as a flow process (Koskela, 2000)

Shingo (1988) contends that the lack of a clear differentiation between operations and processes conveyed an erroneous interpretation that improvements in operations would result in improvements in the production processes as a whole. This reductionist approach equates to the decomposition in the transformation view of production (Koskela, 2000).

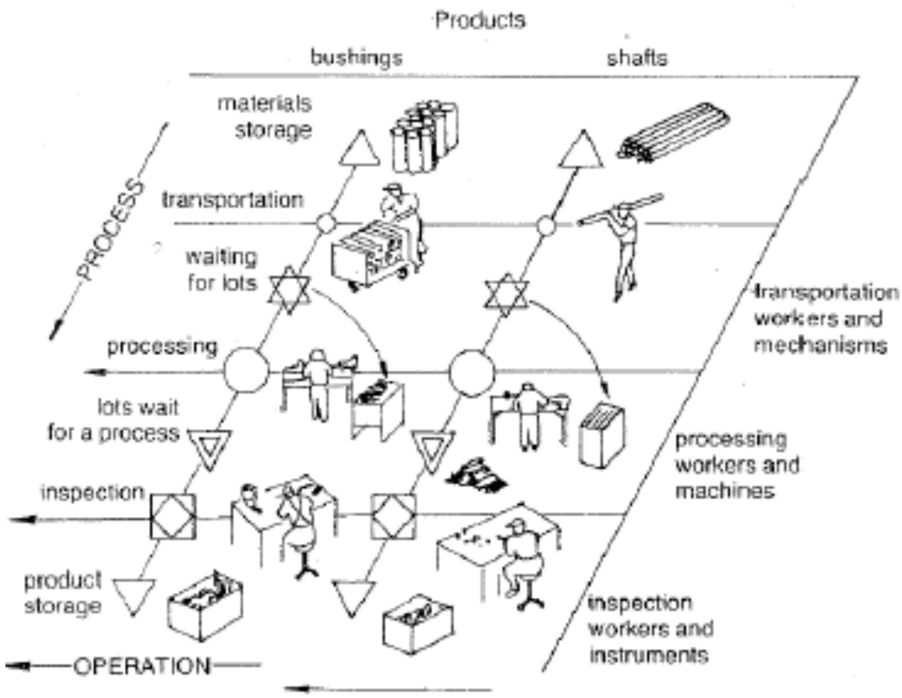

Figure 11 - Two Streams of Production (Shingo, 1988)

In line with the message conveyed by Shingo, and differently to the view propagated by the transformation model (Figure 9), the conceptualisation of production as a flow process (Figure 10) suggested by Koskela (2000) acknowledges explicitly the existence of two types of activities, i.e. transformation or value-adding activities and non-transformation or non-value-adding activities (waste). This distinction is particularly important when the core of the flow concept of production is analysed. In the flow view, time is seen as one attribute (or resource) of production, thus reducing the consumption of such resource is a major goal (Koskela, 2000). Since those two types of activities consume time, the elimination of time waste by cutting the share of non-value-adding activities is promoted as the main principle in the flow view (Koskela, 2000). Thus, compressing lead time by eliminating waste from production processes is a basic improvement according to this view (Koskela, 2000).

Another interesting insight promoted by the introduction of time as a resource is the fact that time is impacted by the uncertainty and variability inherent in production, consequently reducing the variability and uncertainty within flow processes must be seen as essential goal (Koskela, 2000). Because of the aforementioned implications, the incorporation of time as an attribute in production is considered as the main difference between the flow view and the transformation view (Koskela & Howell, 2002). Additional principles related to the flow view include simplification of production process by minimising the number of steps, parts, and linkages, increased flexibility, and increased transparency (Koskela, 2000).

The value view seeks to achieve the best possible value from the perspective of the customer (Koskela, 2000). The consideration of the customer in the conceptualisation of production is the main difference in comparison to the transformation view (Koskela & Howell, 2002). According to Koskela (2000, p.85), this concept of production has its focus on "the interaction between a customer and a supplier (producer), where requirements are provided by the customer and value by the supplier". Thus, the process of capturing customer's requirements, translating it into a design solution, and then producing it accordingly is vital. The improvement of customer value is the main principle that underpins this conceptual view of production.

The underlying idea of the TFV theory is that production has to be managed from these three viewpoints simultaneously (Koskela, 2000). In this respect, it is fundamental that managers have a balanced approach regarding each perspective of production. It is noteworthy that the TFV theory has been also called by the research community on construction management as "lean construction theory" due to its emphasis on principles derived from lean production. So, from now on the term "lean" will be used in the thesis as a reference to this integrated view of production.

Now that the TFV theory of production is properly introduced, it is convenient to elucidate the underlying theory of production upon which the traditional construction project management approach is underpinned. This topic is addressed in the next section.

3.2.2.4 The underlying theory of traditional construction project management approach used in refurbishment projects

On which view of production does the traditional construction project management approach utilised in refurbishment projects rest? In order to answer this question, the elements that constitute such a conventional management approach should be recapped. Based on the literature review presented earlier in this thesis, refurbishment projects have been customarily managed through the application of centralised planning, detailed CPM schedules, command-and-control communication, and after-the-fact tracking.

The shortcomings of the conventional approach have already been discussed in this thesis (please refer to section 3.1.1.3). However, the clarification of the underlying assumptions behind it is primary. The following quote of Howell, Ballard, and Tommelein (2011) illuminates this:

> Traditional practices rest on an assumption that careful development of a project schedule, managing the critical path, and maximising productivity within each activity will optimise project delivery in terms of cost and duration. (Howell et al., 2011, p. 740).

According to the description provided by Howell et al. (2011), it is clear that the traditional management approach applied in refurbishment projects rests on the transformation theory of production. Indeed, as noted by Koskela (2000), construction is normally viewed as a series of transformation (value-adding) activities. As a result, the principles of flow and value generation are commonly neglected (Koskela & Howell, 2002).

Despite the dominance of the transformation theory of production, it is argued that the TFV theory is gaining traction in the construction industry. There are several studies reporting the application of this conceptual framework for designing, controlling, and improving complex production systems in a more systemic perspective (e.g. Howell & Ballard 1999, Ballard, Koskela, Howell, & Zabelle. 2001; Schramm, Costa, & Formoso, 2004; Ballard 2008). Nevertheless, there is still limited evidence regarding practical applications of such theory in refurbishments, in comparison of what is found concerning new building projects. In the following section, the studies that somehow addressed concepts and principles of the TFV theory for improving the performance of refurbishment projects are presented.

3.2.2.5 Lean construction approach to refurbishment projects

While lean theory has been well tested in new construction projects, in the refurbishment sector the same level of practical application has not been undertaken or reported (Kemmer & Koskela, 2012; Kemmer et al., 2013). Indeed, there are few cases in which there is reported use of lean concepts and principles in the management of refurbishment projects (Table 10).

The majority of cases presented in Table 10 concern implementation of lean principles in the construction phase of refurbishment projects (e.g. Ballard, 2000; Horman et al., 2003; Singh, 2007; Pereira & Cachadinha, 2011; Bryde & Schulmeister, 2012, Haarr & Drevland, 2016; Vrijhoef, 2016). Yet, there are also studies focused on design management (e.g. Mitropoulos & Howell, 2002; Tuholski & Tommelein, 2008; Tuholski et al., 2009).

Table 10 - Evidence of Lean principles and methods applied to refurbishment projects (partially adapted from Kemmer & Koskela, 2012)

Authors	Research developed
Ballard (2000)	The research is focused on the development of Last Planner System (LPS), the well-known lean method of production planning and control. The researcher conducted several case studies to evaluate the efficacy of LPS, including an implementation in a building renovation project. Results are encouraging since project was completed on time, on budget, and to the satisfaction of users. This case study is, to the best of the author's knowledge, the first case of lean implementation in a refurbishment project.
Mitropoulos & Howell (2002)	The researchers examine the problems that occur during the design phase of an office renovation project and offer strategies to reduce design rework and duration as well as increasing quality of the design solution. They refer to early involvement of key project members, prototyping, the identification of key constraints, and an accelerated discovery of existing conditions of the building
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.
Singh (2007)	Proposes a framework for production management of renovation projects based on methods to quantify the impacts of constraints on production schedule. The approach aims at improving schedule performance.
Tuholski & Tommelein (2008)	Advocate on the use of the design structure matrix (DSM) methodology on a seismic retrofit project and demonstrate that it is useful for optimizing design process. The transparency provided by the use of DSM helps practitioners to identify interactions at different levels improving considerably the communication within design process.
Tuholski et al. (2009)	Demonstrate the usefulness of cross-functional process charts for improving project delivery process in two complex retrofit projects where seismic isolation bearings were installed. The charts serve as a tool for representing project complexity in order to enable project participants to identify opportunities for improvements.
Ho (2009)	Develops an automated method to identify interactions between tenants and crews in renovations of occupied buildings in order to reduce disruptions on site. This is made possible by a better understanding of the dynamic nature of renovations projects along with the use of a computer-aided prototype.
Lahtinen et al. (2009)	The intervention implemented 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 construction site, webpages containing project information such as schedules, etc.).
Pereira & Cachadinha (2011)	The application of lean tools and techniques for managing production in rehabilitation works (e.g. value stream mapping, pull planning, 5S) is assessed in this study. Findings indicate that the applicability of lean tools and techniques is feasible and useful.
Bryde & Schulmeister (2012)	The adoption of lean principles to a refurbishment project in Germany is assessed. While some aspects such as visual management and weekly meetings had a positive impact in the project, other lean tenets such as pull-drive scheduling and minimising stocks on site were difficult to be implemented. Enablers and barriers are discussed.
Ladhad & Parrish (2013)	The efficacy of lean practices for achieving energy performance goals in a retrofit is highlighted. This refers to, for example, early integration of design and construction teams and continuous improvement. Last Planner System is also mentioned as a useful tool for improving coordination and integration between project participants.
Haarr & Drevland (2016)	The researchers point out the reasons for an unsuccessful implementation of lean principles and methods during the construction phase in a rehab project in Norway. Lack of understanding of underlying lean principles, lack of collaboration, poor implementation strategy, and high level of unforeseen site conditions were considered the main causes of failure in the implementation of the lean management approach.
Vrijhoef (2016)	The potential of lean principles (e.g. continuous flow, pull planning) and industrialised product technology (e.g. standardisation, prefabrication) is demonstrated through two housing renovation projects. Substantial increases in productivity in comparison to traditional management approach are achieved in both cases. The use of multi-skilled teams was instrumental in the implementation of the lean approach.

Findings from the studies mentioned in Table 10 demonstrate that the lean theory can be applied to improve the management and performance of refurbishment projects. Reported benefits include, for example, reliable workflow on site (Ballard, 2000), optimised design process (Tuholski & Tommelein, 2008), improved logistics (Pereira & Cachadinha, 2011), enhanced coordination and integration between project participants (Ladhad & Parrish, 2013), and increases in productivity (Vrijhoef, 2016). Also, findings suggest that a proper understanding of the refurbishment context is vital to devise appropriate solutions to this particular project environment (e.g. Mitropoulos & Howell, 2002; Singh, 2007).

Despite the advantages mentioned above, it is important to point out the implementation issues reported in some studies. For example, Bryde and Schulmeister (2012) underline the difficulty in applying pull-drive scheduling and minimising stock held on site via just-in-time delivery on the refurbishment of a building in Germany. Haarr and Drevland (2016) identify several problems in the application of lean methods through the construction phase in a rehabilitation project in Norway, such as lack of understanding of lean principles from project participants, absence of a leader to facilitate the implementation, lack of collaboration, and poor implementation strategy as many tools and techniques were implemented at once.

Finally, it is noteworthy that there are also examples of lean implementations in projects that have similar characteristics in comparison with refurbishment in terms of project complexity. For instance, the studies developed by Schramm, Rodrigues, and Formoso (2006) and Cuperus, Wamelink, and Resodihardjo (2010) do not refer directly to refurbishments, but they approach construction projects with complex characteristics, akin to the refurbishment context. Both cases demonstrate that significant benefits can be achieved through the use of managerial practices in line with the lean theory such as Production System Design, Last Planner System, Visual Management, Line of Balance, etc. Clearly, lessons can be learned from those experiences in order to improve the way production is managed in refurbishment projects.

Based on the analysis of the literature, a set of managerial tools and techniques in consonance with lean concepts and principles is suggested as candidates for initial testing. Next, those candidate solutions are introduced.

3.2.2.6 Candidate solutions for production management in refurbishment projects

This section provides an overview on managerial tools and techniques considered by the author of the thesis as candidate solutions for production management in refurbishment projects. They have been based and further developed on the work reported by Kemmer et al. (2013). It is argued that they have some sort of connection to the concepts and principles of the TFV theory of production (Koskela, 2000) as indicated in Table 11.

Table 11 - Candidate solutions and the TFV theory of production (Koskela, 2000)

Candidate Solutions	TFV Concepts	TFV Principles
Production System Design	Transformation	Decompose the production tasks
	Flow	Reduce the share of non-value adding activities (waste)
		Reduce variability
		Simplify
	Value	Ensure that all requirements get captured
Last Planner System	Transformation	Decompose the production tasks
	Flow	Reduce the share of non-value adding activities
		Compress lead time
		Reduce variability
	Value	Ensure that all requirements get captured
		Ensure the flowdown of customer requirements
Line of balance	Transformation	Decompose the production tasks
	Flow	Reduce the share of non-value adding activities
		Compress lead time
		Reduce variability
Cellular Manufacturing / Multiskilling	Transformation	Realise value-adding activities efficiently
	Flow	Reduce the share of non-value adding activities (waste)
		Compress lead time
Prefabrication / Standardisation	Flow	Reduce the share of non-value adding activities (waste)
		Compress lead time
		Increase flexibility
	Value	Improve customer value
Mass customisation	Flow	Increase flexibility
	Value	Improve customer value
Benchmarking	Flow	Compress lead time

It is worth mentioning that this list is not exhaustive, rather it serves as a starting point for practical testing and validation.

3.2.2.6.1 Production System Design

According to Ballard et al. (2001, p. 2) "the first task in any productive endeavour is production system design, which extends from global organization to the design of operations". The production system design aims at tackling the three objectives of production system, i.e. do the job, maximize value, and minimise waste (Koskela, 2000).

Slack et al. (1997) argue that the objective of the production system design (PSD) is to debate and convert the planned production strategy into a set of decisions that will serve as guidance for the management of different activities. For instance, those decisions refer to definition of project execution strategy, study of workflows, identification and design of critical processes, and definition of capability of production resources (Schramm et al, 2004). Ballard et al. (2001) contend that PSD should also create the appropriate conditions for control and improvement.

It is argued that the accomplishment of the production system design can be used as a means to cope with the uncertainty inherent to refurbishment projects. Further information on PSD can be found in Ballard et al. (2001), Tsao et al. (2004), Tsao (2005), and Schramm et al. (2004; 2006).

3.2.2.6.2 Last Planner System

The Last Planner System (LPS) aims to produce reliable workflow and stabilises the project. According Ballard (2000, p. 3-2), the LPS "is a philosophy, rules and procedures, and a set of tools that facilitate the implementation of those procedures". An overview of LPS is shown in Figure 12.

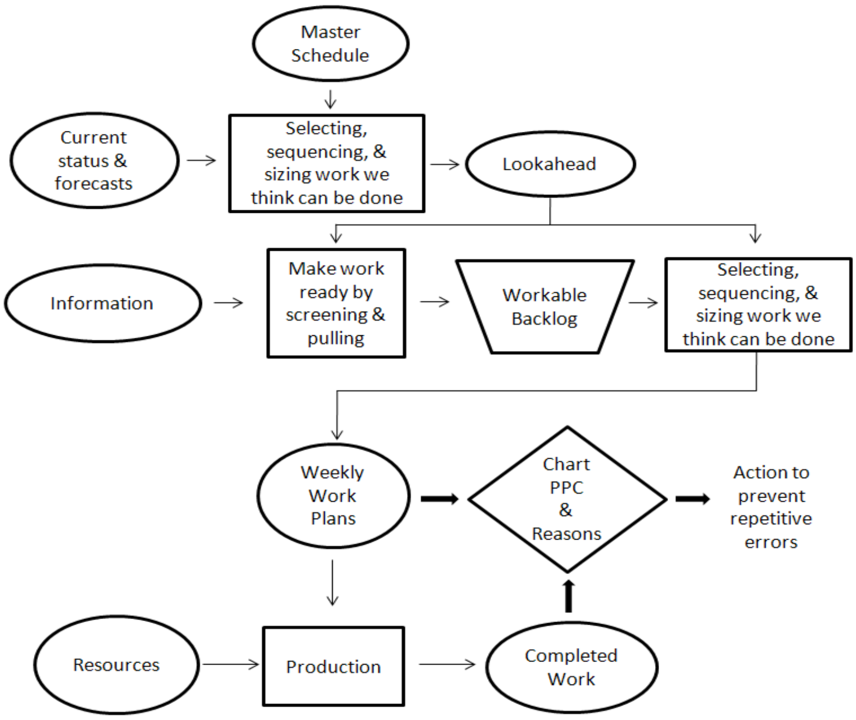

Figure 12 - The Last Planner System (LCI, 1999)

Based on Ballard (1997; 2000) and Ballard and Howell (2003), Koskela, Stratton, and Koskenvesa (2010, p. 539) 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 Plan – 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 Plan – 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 (WWP) – 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; and
- Percent Plan Complete and analysis of reasons for non-completed tasks – this is about improving the project planning by continual assessment and learning from failure. Percent Plan Complete (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.

It is argued that the Last Planner System is an appropriate tool for managing production in refurbishment projects because it is better equipped to cope with the uncertainty and variability inherent to refurbishments. This refers to gradual detailing of plans, removal of constraints before starting works on site, use of short control and learning cycles, learning from mistakes, and high involvement of project participants in the creation of plans.

Further information on LPS can be found in Ballard (1997; 2000), Ballard and Howell (2003). For a demonstration of LPS implemented in the context of social housing retrofit please refer to Kemmer, Biotto, Chaves, Koskela, and Tzortzopoulos (2016).

3.2.2.6.3 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. Further information on LOB can be found in Soini, Leskela, and Seppänen (2004), Seppänen and Aalto (2005), Kemmer, Heineck, and Alves (2008), and Kenley and Seppänen (2010).

3.2.2.6.4 Visual management

According to Tezel (2011, p. xxv), 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 to 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. Further information on visual management can be found in Sacks, Treckmann, and Rozenfeld (2009), Tezel, Koskela, and Tzortzopoulos (2010), Tezel, Koskela, Tzortzopoulos, Koskenvesa, and Sahlstedt (2011).

3.2.2.6.5 Cellular manufacturing

Production cell is largely used in the manufacturing industry (Hyer & 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 & Rogers, 1991). Rother and Harris (2001) define cells as an arrangement of people, machines, and methods in which the activities are close to each other and occur in sequential order, whereby the parts are processed in a continuous flow in small batches sizes.

Hyer and Brown (1999) argue that cell manufacturing (CM) goes beyond that a simple physical configuration. They 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" (Hyer and Brown, 1999, p. 560).

According to dos Santos, Moser, and Tookey (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. The same authors argue that CM captures several lean practices within a single environment, thus it can help in the implementation of lean initiatives in the construction sector.

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 & 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. Further information on the application of production cells in construction projects can be found in Santos et al. (2002) and Mariz, Picchi, Granja, and Melo (2011).

3.2.2.6.6 Multiskilling

Multiskilling refers to workers who possess several skills that allow them to execute different tasks. According Wang, Goodrum, Haas, and Glover (2009), this strategy has proved beneficial for both workers and construction companies as it increases productivity, quality, and continuity of work, and also reduces skill shortages through better utilization of the current labour force.

The use of multi-skilled workers can be very useful in the context of refurbishment projects. In a project environment characterized by different small labour operations, the use of multi-skilled teams can support continuous work flow and improve the efficiency of the production system by reducing disruptions on site and compressing the project lead time. Further information on multi-skilled teams in construction can be found in Maturana, Alarcon, and Deprez (2003), Sacks and Goldin (2007), and Cuperus et al. (2010).

3.2.2.6.7 Prefabrication/Standardisation

It is largely acknowledged that prefabrication and standardisation in construction processes lead to increased quality and reductions of cost and time (Goodier & Gibb, 2007). Thus, it makes sense to have this approach to the refurbishment sector. As a matter of fact, there is evidence of improvements in terms of labour productivity in refurbishment projects through the use of prefabricated and standardised building elements (Vrijhoef, 2016).

Further information on prefabrication and standardisation in construction can be found in Höök (2006), Höök and Stehn (2005; 2008), and Roy, Low, and Waller (2005).

3.2.2.6.8 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 convenient to the refurbishment sector. The unpredictability associated to refurbishment projects can lead to a project environment similar to what is found in a customisation process. Therefore, pursuing the ability to cope with it in an efficient way is definitely an objective worth looking for. Further information on mass customisation applied in construction projects can be found in Kemmer et al. (2010), Lu, Olofsson, and Stehn (2011), da Rocha (2011), and da Rocha, Kemmer, Meneses, and Formoso (2013).

3.2.2.6.9 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. Further information on benchmarking in construction can be found in Costa, Formoso, Kagioglou, and Alarcon (2004), Costa, Formoso, Kagioglou, Alarcon, and Caldas (2006) and Ramirez, Alarcon, and Knights (2004).

3.2.3 Discussion

Several conclusions can be drawn based on the literature review on project complexity and theory of production. Firstly, the acknowledgement of refurbishments as complex projects is primary for selecting a suitable management approach. This insight implies that managers have to better understand the peculiarities of refurbishment (e.g. interdependence between tasks and trades, sources of uncertainty and variability) for adopting methods of production control capable to mitigate the difficulties created by those typical features. In other words, the lack of understanding of the complex nature of refurbishment projects can lead to bad managerial decisions and ultimately to poor project performance. Although this seems an obvious inference, it is important to be highlighted since companies are still using traditional methods for managing construction in refurbishments as showed earlier in this thesis.

Secondly, the conventional construction management approach applied in refurbishments is ineffective because it rests on a deficient theoretical background, i.e. transformation theory. The problem with this view is that it ignores the existence of non-value-adding activities in production. Indeed, wastes such as waiting, moving, and storing inventory are not usually represented in Critical Path Models (Koskela, 1992). Also, the transformation view does not recognise the uncertainty and variability inherent in production, hence it does not seek to reduce them systematically as the flow view does (Koskela & Howell, 2002). Besides, it fails to create and deliver value for customers because it neglects the complex context in which projects take place. In complex and uncertain projects, customer requirements are not clearly defined at the outset, therefore making use of techniques that push for early decisions and local optimisation is misunderstand project's nature (Koskela et al., 2002).

Thirdly, the TFV theory (Koskela, 2000) is the theoretical foundation that should serve as a reference basis for managing and improving production in refurbishment projects. It is a more powerful reference basis as it integrates the three major views production, namely, transformation, flow, and value. Moreover, it is contended that this theory has a better approach regarding waste in comparison to traditional management. Indeed, in the flow view of production, the elimination of waste through the reduction of the share of non-value-adding activities is a major goal. Besides, there are several tools and techniques that support the practical implementation of this new management approach. On this regard, a number of candidate solutions are suggested for initial testing.

Fourthly, findings from the studies cited in Table 10 indicate that there is a potential of using lean solutions for improving performance of both design and construction in refurbishment projects. Several managerial methods and practices have been successfully tested, thus proving that lean construction tools and techniques are suited to cope with the uncertainty and variability inherent to refurbishment projects. Yet, lessons can be learned from the implementation problems reported in some studies. For example, the difficulty to apply lean principles to the refurbishment context, as noted by Bryde and Schulmeister (2012), indicate that adaptations might be necessary for allowing an effective application of tools and techniques. In addition, Haarr and Drevland (2016) stress the importance of the implementation strategy, when they contend that tools and techniques should be implemented gradually, to avoid an overload of training sessions and demotivation of people not used to the lean approach. Pereira and Cachadinha (2012) also recommend a gradual implementation for allowing sufficient time for training and practice.

Lastly, an important aspect observed in those studies refers to the use of managerial methods and practices that consider principles of flow process design, control, and improvement. For example, last planner system, cross-functional charts, design structure matrix, multiskilling, identification of key project constraints, early involvement of key project members, standardisation, prototyping, and 5S. It is argued that they can be considered as means to take into account lean principles such as waste reduction, pull planning, variability reduction, continuous flow, process transparency, collaboration, learning, and improvement.

3.2.4 Conclusions

The most evident conclusion that follows from this discussion is that the use of traditional construction management approach for managing production in refurbishment projects is no longer tenable because it is not based on the best theory available. As stressed by Koskela and Howell (2002, p. 300), "it rests on a faulty understanding of the nature of work in projects".

The management of construction in refurbishment projects must be based on the TFV theory (Koskela, 2000). It is argued that the integration of the three concepts of production (transformation, flow, and value) makes it a more powerful reference basis for modelling, designing, controlling, and improving complex production systems. It is therefore the reference basis upon which managerial methods and practices should be underpinned.

It is argued that the flow view of production is particularly valuable from the perspective of this investigation, which is focused on production management in refurbishment projects. While principles associated to the value view can be seen as more suited for managing and improving the design stage, empirical evidence suggests that flow-concept related principles are instrumental for enhancing performance of the construction phase. Thus, it is contended that the refurbishment context offers an interesting opportunity to apply principles such as waste reduction, lead time compression, and variability reduction.

A list of candidate solutions for managing production in refurbishment projects was suggested to be tested and validated by construction organisations with the purpose of ensuring that their use improves production performance. Evidently, the best way to assess the efficacy of the lean approach is experimenting. It is by practicing and testing that the necessary awareness to attain a continuous improvement is developed.

The second part of the literature review served to set the foundations for this investigation. In the following chapter, the development of the initial version of the method proposed in the thesis is presented.

Chapter 4 Artefact development

This chapter presents the steps taken by the researcher for the development of the solution proposed in the thesis, namely, the method for construction management in refurbishment projects. As illustrated in Figure 13, the research process starts off with the identification and understanding of a relevant problem and ends up with the elaboration of the first version of the method. In the following sections, furthers details are provided on each phase of this initial stage of the research process.

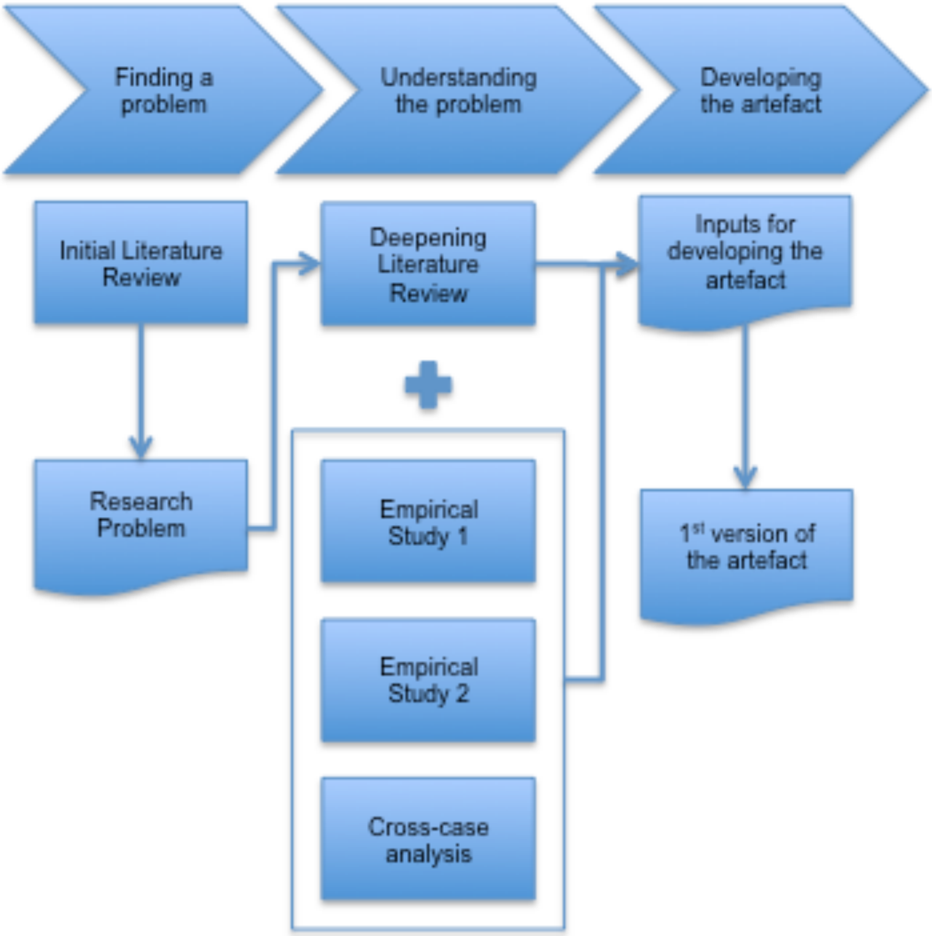

Figure 13 - Research process adopted for developing the artefact

4.1 Finding a problem

According to Kasanen et al. (1993), the first step in a design science research is the identification of a relevant practical problem, which has also a potential for theoretical contribution (Figure 14).

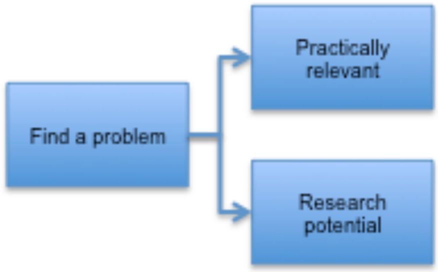

Figure 14 - First phase of artefact development (based on Kasanen et al., 1993)

This task was accomplished through an initial literature review focused on construction management in refurbishment projects, which is presented in section 3.1.1 in this thesis. From a theoretical perspective, the problem is the lack of a construction management approach based on an appropriate theory of production and tailored to suit the basic nature of refurbishment projects. Also, studies on construction management in this particular project setting are scarce when compared to the amount of research developed around the broad refurbishment realm. Clearly, there is a gap in this research domain. In practical terms, problems in managing refurbishments are found in several countries and there is evidence showing that such projects present poor performance when compared to new build endeavours (McKim et al., 2000). Moreover, it was found that construction organisations are still using inappropriate methods to manage refurbishment projects (Henrich, 2009). As a result, numerous types of wastes have been identified such as waiting time, disruptions in performing tasks on site, unnecessary transport, among others. It is contended that such problems are likely to lead to unsatisfactory project performance in terms of low productivity, project delays, cost overrun, and annoyance for the users of the building. This first phase was conducted between July and December 2012.

4.2 Understanding the problem

In order to better understand the problem identified in the first phase of the research, three main activities were conducted: a) literature review, b) empirical studies, c) cross-case analysis (Figure 15). These are detailed in the following subsections.

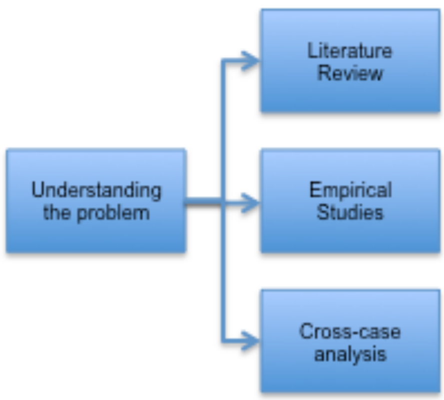

Figure 15 - Activities conducted to better understand the problem

4.2.1 Literature Review

The literature review served to gain a deep understanding on the problem identified previously and also to identify the theoretical background that could be used to underpin the artefact devised in the study. Therefore, in addition to construction management in refurbishment projects, the review focused on subjects such as project complexity, theory of production, production management concepts and principles, and managerial methods suitable as candidate solutions for managing construction in refurbishment projects.

The key inputs extracted from the literature review that contributed to the development of the method proposed in the thesis are summarised below. The author selected these inputs because they address the most important issues related to construction management in refurbishment projects. They tackle not only the basic features of refurbishments but also shed light on how to deal with such particular projects in an appropriate manner according to recommendations from the literature.

- The existing asset and the operations in the existing building are the most distinguishable characteristics of refurbishment projects. These particular features influence the management of works on site as they tend to increase the complexity of the project;
- The acknowledgement of the context in which refurbishment projects takes place is primary for defining an appropriate construction management approach. Refurbishments are complex projects. Therefore, the use of management practices and methods capable to handle such complexity (e.g. Production System Design, Last Planner System, Visual Management, Prefabrication, Standardisation) is recommended. It is worth mentioning that this recommendation tackles an issue identified during the literature review (section 3.1.2.3), namely, the lack of indication of managerial methods to support the implementation of guidelines for improving the management of refurbishment projects;
- The management practices and methods used in refurbishment projects should be based on a sound theoretical foundation. This refers to a theory of production capable of coping with refurbishment features, namely, the TFV theory (Koskela, 2000). Similarly to the previous recommendation, this one also addresses another issue raised in section 3.1.2.3, namely, the lack of theory for underpinning management practices;
- Lean principles, tools, and techniques were suggested as candidate solutions for designing, managing and improving production systems of refurbishment projects. The indication of tools and techniques fills a gap identified in the literature concerning the management of refurbishment projects as discussed in section 3.1.2.3;
- Six categories of guidelines for improving the management of refurbishment works were identified through the literature review. These are also suggested as candidate solutions for improving the management of refurbishment projects.

4.2.2 Empirical studies

Two empirical studies were conducted to investigate the intrinsic characteristics of refurbishment projects. This refers to the way that refurbishments are carried out, the typical problems faced at the construction phase (e.g. the influential factors affecting planning and control effectiveness), and the identification of current managerial practices (e.g. methods used for production planning and control) adopted by companies for managing construction. The knowledge gained in this phase served to deepen the understanding on issues related to the management of construction in refurbishments as well as identifying opportunities for improvement.

4.2.2.1 Empirical study 1 – Refurbishment of houses

The first empirical study was conducted in a housing association[16] based in Manchester between December 2012 and May 2013. Information was collected through semi-structured interviews (Table 12), documental analysis (Table 13), and non-participant observations of planning meetings and works on site (Table 14). The information gathered throughout the study was validated through a meeting involving representatives of the housing association and the contractor. The selection of people to be interviewed, as well as the documents analysed and meetings observed, was based on the connection with the management of construction in the refurbishments schemes[17] carried out by the housing association. They represent the sources of evidence of the study and are summarised in the tables as follow.

Table 12 - List of interviews carried out in empirical study 1

<table>
<tr><th>Interview</th><th>Interviewee's position</th><th>Organisation</th><th>Job functions</th></tr>
<tr><td>1</td><td>Property Services Coordinator</td><td>Housing Association</td><td rowspan="2">Overseeing effective delivery of refurbishment schemes, stock condition surveys, and other daily tasks such as post inspections, specification of major repairs, budgeting</td></tr>
<tr><td>2</td><td>Property Services Coordinator</td><td>Housing Association</td></tr>
<tr><td>3</td><td>Strategic Information Manager</td><td>Housing Association</td><td>Overseeing property services information requirements, data gathering and storage</td></tr>
<tr><td>4</td><td>Building Surveyor</td><td>Consultant</td><td>Quantity surveying, project management, quality control of works on site, handover</td></tr>
<tr><td>5</td><td>Project Manager</td><td>Contractor A</td><td rowspan="2">Management and delivery of refurbishment schemes for clients, perform tasks such as procurement, production planning and control, and management of subcontractors</td></tr>
<tr><td>6</td><td>Project Manager</td><td>Contractor B</td></tr>
<tr><td>7</td><td>Site Manager</td><td>Contractor A</td><td rowspan="2">Responsible for managing health and safety, workforce, programme, and quality</td></tr>
<tr><td>8</td><td>Site Manager</td><td>Contractor B</td></tr>
</table>

[16] According to the Department for Communities and Local Government (DCLG) housing associations are defined as "independent societies, bodies of trustees or companies established for the purpose of providing low-cost social housing for people in housing need on a non-profit-making basis". The terms Registered Social Landlords and Private Registered Providers of Social Housing are also used to represent these organisations, but currently the term Housing Association has been used as the generic name for all social landlords not covered by local authorities (DCLG, 2012).

[17] The term "refurbishment scheme" refers to the refurbishment of a group of houses in a certain area.

Table 13 - List of documents assessed during the study

Document	Title	User	Information displayed in the document
1	Stock condition or next replacement date report	Housing Association	Shows the dates of the next replacement of components and systems (e.g. windows, insulation, painting, fencing, gutters, chimneys, heating, etc.) as well as the dates for refurbishing areas of the house (e.g. kitchen, bathroom)
2	Lifecycle listing	Housing Association	Informs the lifespan of several areas of the house (e.g. bathrooms, kitchens, etc.) and their components (e.g. boiler, fire alarm, doors, windows, etc.). It is reference for producing the next replacement date report
3	Insulation and heating report	Housing Association	Contains information on the insulation and heating status of the houses (e.g. property type and specification, type of insulation and heating systems installed, installation and replacement dates, etc.)
4	Post-inspection record	Housing Association	Comprises post-inspection dates and feedbacks from tenants on the quality of works
5	Quality design guide	Housing Association, Consultant, Contractors	Sets design standards and aspirations from the Housing Association's point of view. Includes aspects such as function, context, access and inclusion, sustainability, maintenance, detailing and material, among other issues related to building design
6	Kitchen and door colour choice form	Housing Association, Consultant, Contractors	Shows in a visual way the options available for some kitchen components (e.g. worktop colours, handle and kitchen units design) and doors' specifications (e.g. door finish colour, frame types, etc.)
7	Kitchen layout	Housing Association, Consultant, Contractors	Drawing containing the layout of the new kitchen, including dimensions to enable the measurement and location of electrical switches and outlets. Also, it indicates the position of the water meter
8	Master spreadsheet	Housing Association, Consultant, Contractors	Assists the managers of the housing association on the management of refurbishment schemes by listing information such as property type, building survey status, tenant choices, key dates (e.g. planned/actual start and end dates of works on site, survey date, inspection dates, etc.), certificates (e.g. gas and electrical tests)
9	Meeting minutes (kick-start and progress meetings)	Housing Association, Consultant, Contractors	Comprises the issues discussed during the meetings such as tenancy needs, refurbishment programme, scope of works, communication standards, contact details, design issues (e.g. material specifications), etc. Further details on topics addressed in each meeting are provided in the following sections
10	Customer Induction Information or Customer Information Pack	Contractors, Tenants	Provides information for clients on the refurbishment process including the working hours, health and safety procedures, construction programme, contact details, etc.
11	Notice letters	Consultant, Contractors, Tenants	Informs tenants on important refurbishment milestones such as the date set for surveying the house, the start date of works on site, and also serves to communicate other issues, for instance, when the contractor has no access to the house, reasons of delays, etc.
12	Site visit report	Housing Association	Assesses the tenant's satisfaction with regards to works carried out on site and evaluates the performance of contractors
13	Provisional list	Contractors	Comprises the list of refurbishment schemes set for the year. It is organised by geographical area and includes information such as the works agreed, sequencing of schemes, cost estimates, and contact numbers

Table 14 - Observations carried out throughout the study

Observation	What was observed	Place where the observation was conducted
1	Progress meetings	Housing Association Office
2	Site meetings	Site compound
3	Refurbishment works	On site (refurbishment of three kitchens)

The documents listed in Table 13 are used in the preplanning stage of refurbishments, i.e. they support the tasks necessary to set up the schemes planned yearly. The next step is the creation of production plans for managing works on site in each refurbishment scheme. As the focus of the thesis is on construction management, a section called "existing production planning and control system" has been created to explain in detail how construction is managed in this specific project context. Thus, the documents used in the production planning and control process are described in that particular section.

4.2.2.1.1 Characteristics of refurbishments in the context of a housing association

The housing association investigated in this study is responsible for over 18000 homes across the North West and Yorkshire. A significant number of properties, over a thousand, are refurbished each year to ensure the provision of the highest standard of accommodation possible. According to managers of the housing association, approximately 98% of the properties are occupied during the refurbishment work.

The housing association works with two contractors and one consultant. The former carries out works on site while the latter works as a building surveyor conducting surveys in order to produce the schedule of works for the refurbishments and as a clerk of work carrying out post-inspections and checking the quality of workmanship at the handover phase. These companies are also involved in the consultation process led by the housing association and they constitute the core project team for delivering the refurbishments planned yearly. Tenants, subcontractors, and suppliers complete the list of people or organisations involved in the delivery of refurbishments.

4.2.2.1.1.1 Types of refurbishments

There are different types of refurbishments in the context of a housing association. They vary according to the scope of works, for instance, it might involve works in areas such as kitchens and bathroom, or upgrades in terms of building components such as windows, doors, fences, boilers, heating systems, roof repairs, etc. The refurbishment of kitchens and bathrooms are more complex and time consuming than the replacement of building components, since they involve more works to be done. For example, a typical kitchen upgrade involves works such as rip out (i.e. removing kitchen units, tiles, and flooring), strip out (i.e. removing wall paper), plumbing and electrical systems, plastering, wall tiling, flooring, kitchen's fitting, and decoration. Therefore, the researcher decided to focus this empirical study on the refurbishment of kitchens. Table 15 shows the average lead times for the most common types of refurbishments.

Table 15 - Average lead time for the most common types of refurbishments

Ref.	Area refurbished or building component replaced	Lead time
1	Kitchen, bathroom, and boiler	15 days
2	Kitchen and boiler	11 days
3	Kitchen	10 days
4	Roof	5 days
5	Bathroom	3 days
6	Heating	2 days
7	Fence	2 days
8	Boiler	1 day
9	Windows (five on average per house)	1 day
10	External doors (two on average per house)	1 day

Since there are no as-built drawings available for each property the scope of works of a given refurbishment is based on the information about the condition of the house. In this respect, managers of the housing association use an asset management database which contains information derived mainly from the stock condition surveys, but also coming from operatives who work for the maintenance team as well as from feedback provided by the Housing Management Team, a department that logs the complaints made by tenants. The information held in this database is updated by surveyors, who are constantly visiting homes and gathering data, such as when the property was built, how old is the kitchen and other areas of the house as well as building components like window and doors for example. If they do not know the exact date they judge from experience. This information serves as input when planning future refurbishments.

4.2.2.1.1.2 Preplanning stage

The refurbishment of houses in the context of a housing association has a particular challenge, which is to work in an occupied building. This requires a high level of coordination and communication in order to avoid disturbances to the tenants and disruptions in the construction workflow. Therefore, before going on site, there is a planning stage that involves meetings with representatives from the housing association, contractors, and the consultant. It is noteworthy that contractors work with subcontractors that carry out works such as plumbing and electrical systems, wall tiling, flooring, and decoration, but subcontractors do not attend these meetings at this stage.

There is an initial meeting called “pre-contract meeting” which takes place at the beginning of each financial year. At this time, the housing association has already set the list of properties subject to refurbishment for the entire year based on the information available in the asset management database. This meeting is set up to go through the contractual documents and to make clear what the housing association expects from contractors and the consultant who are informed about the works they are required to carry out and the specifications they should use in terms of flooring, paints, tiles, amongst other technical matters. It is noteworthy that the specifications of materials utilised in the refurbishments are standardised. In addition, the housing association sets some ground rules from a communication aspect, such as information on work time allowance, quality standards of the works, how long in advance a company should give notice to tenants informing about home visits, how to protect tenants belongings, etc.

There is also a meeting called "kick-start meeting". Basically, it aims to reduce any possibility of things going wrong on site and it involves the same participants from the "pre-contract meeting" plus the Housing Management Team (HMT). The HMT is a department within the housing association responsible for letting properties, managing rent, and for looking at the general wellbeing of a particular area. The kick-start meeting is not focused on technical aspects of the refurbishments, but it is the moment when the HMT tells contractors and consultant about any tenant issues before they arrive on site. For example, they are made aware of anti-social behaviour in specific areas, types of complaints filed by tenants (e.g. "doors are not working properly"), and supportive needs.

Another type of meeting is the "progress meeting". Basically, the contractor and the consultant report to the housing association of progress made at current refurbishment schemes, such as areas of the refurbishment where the contractor is performing well, areas for improvement, and actions taken to achieve targets previously set. Also discussed are the issues around forthcoming schemes. Additional topics addressed include: health and safety, requests for information, and the assessment of tenants satisfaction rate. This meeting takes place on a monthly basis and it is carried out separately for each contractor.

The core project team (housing association, contractors, and consultant) is also responsible for carrying out consultations. Choices are given to the residents with regards to material's styles (e.g. types of sink and tap, wall tiles, etc.) and designs (e.g. kitchens, fences, windows, handle, etc.). Some consultations are conducted on an individual basis (e.g. refurbishment of kitchens and replacement of fences) whilst others are carried out on a collective basis (e.g. windows installation). Visual aids such as choice menus (Figure 16) containing pictures of the different types of materials that will be used in the kitchen (e.g. sinks and taps, handles, flooring, etc.) and small prototypes (e.g. mini doors) are also used in this process to help tenants to make quick decisions.

Figure 16 – Images extracted from the kitchen colour choice form

4.2.2.1.2 Existing production planning and control system

This section sheds light on the production planning and control system utilised by a construction company for managing refurbishments in the context of a housing association. The scheme examined in this study comprises the renovation of kitchens in three different houses. It refers to the installation of new furniture (new kitchen units and the replacement of worktops and sink tops), flooring, wall ceramic tiling, gas and water pipes, electrical wiring and cables, and decoration (wall paper and painting). It is worth mentioning that apart from the data presented in Table 16, which contains records from two contractors (here named as A and B), all information provided in this section refers to the process conducted by contractor A, contractor B contributed to the initial phases of the study but became unavailable throughout the development of the research.

The production planning and control process starts with the list of properties provided by the housing association. This list contains the number of houses subject to refurbishment during the year. Based on that, the project manager who works for the contractor sets a plan that takes into account the geographical location of the houses and the scope of works related to each of them. The output from this first analysis is a master plan containing the number and sequence of refurbishment schemes that will be undertaken throughout the year. On average, the number of houses within a scheme ranges from 5 to 20 houses. In some cases this number can go up to 50 properties, but there are also cases when the contractor has to go to some areas to refurbish just four, two, or even one house. The next step is the development of production plans for each refurbishment scheme.

The basic organisational structure deployed by the contractor to manage the construction phase of refurbishment schemes involves a project manager, a site manager, a tenant liaison officer (TLO), a foreman, and the operatives. In the refurbishment of kitchens, the contractor is in charge of executing rip out (i.e. removing kitchen units, tiles, and flooring), plastering, kitchen's fitting, and snagging. Subcontracted services include: strip out (i.e. removing wall paper), plumbing and electrical systems, wall tilling, flooring, and decoration. Table 16 presents parameters used for production planning and control of a refurbishment of a single kitchen and indicates the items of work conducted along with their respective cycle times. Also, the last column of the table indicates the day in which each task is performed during the execution of the refurbishment.

Table 16 - Planning parameters for the refurbishment of a kitchen

	Contractor A			Contractor B		
Item	Item of work	Cycle time (hours)	Day	Item of work	Cycle time (hours)	Day
1	Rip Out & Strip Out	2	1	Strip Out	4	1
2	Plumbing	2	1	1st fix electrics	8	2
3	Electrics	7	2	Plastering	4	3
4	Plastering	7	3	Fit kitchen & Plumbing	8	4
5	Fit kitchen	6	4	Tile kitchen	4	5
6	Tile kitchen	4	5	2nd fix electrics	2	6
7	Screed floor (dry time)	1 (2)	6	Decoration 1st phase (dry time)	4 (4)	7
8	Lay floor	2	7	Decoration 2nd phase	4	8
9	Decoration 1st phase (dry time)	4 (4)	8	Screed floor (dry time)	2 (4)	9
10	Decoration 2nd phase	8	9	Lay floor	4	10
11	Handover (snagging & cleaning)	8	10	Handover (snagging & cleaning)	2	11

As shown in Table 16, the refurbishment of a kitchen is planned to take ten and eleven working days for contractor A and B, respectively. However, the contractors normally inform tenants that the works are going to take 15 days. This buffer is added to cope with any unforeseen situations that might disrupt works on site. Also, it is possible to note that contractors consider in their planning partial days of work. According to them, this happens mainly because of the uncertain nature of the refurbishment work that makes it difficult to have a perfect synchronization of trades on site.

According to the site manager (contractor A), the company normally finishes works within the 10 days as planned. This was confirmed during the observations carried out on site when the researcher had a chance to observe the refurbishment of three kitchens (K1, K2, and K3). Two houses (K1 and K3) were occupied during the refurbishment and one (K2) was unoccupied. Eight hours (480 minutes) is the maximum period of time available for working each day. The data collected on site is summarised in Table 17.

Table 17 - Planned versus actual data for the refurbishment of kitchens

Refurbishment of kitchens			Cycle times (minutes)			
Contractor A		Day	Planning parameters	Actual data		
Item	Item of work			K1 Occupied	K2 Void	K3 Occupied
1	Rip Out & Strip Out	1	120	100	85	120
2	Plumbing		120	100	90	120
3	Electrics	2	420	360	270	285
4	Plastering	3	420	360	225	405
5	Fit kitchen	4	360	330	240	310
6	Tile kitchen	5	240	180	225	210
7	Screed floor (dry time)	6	60 (120)	N/A	N/A	30 (120)
8	Lay floor	7	120	60	60	90
9	Decoration 1st phase (dry time)	8	240 (240)	210 (240)	150 (240)	210 (240)
10	Decoration 2nd phase	9	480	300	300	270
11	Handover (snagging & cleaning)	10	480	160	160	160

The site manager is responsible for devising a plan for each refurbishment scheme set in the master plan produced by the project manager. This plan contains the list of properties, addresses, items of works, and dates. Figure 17 illustrates this plan.

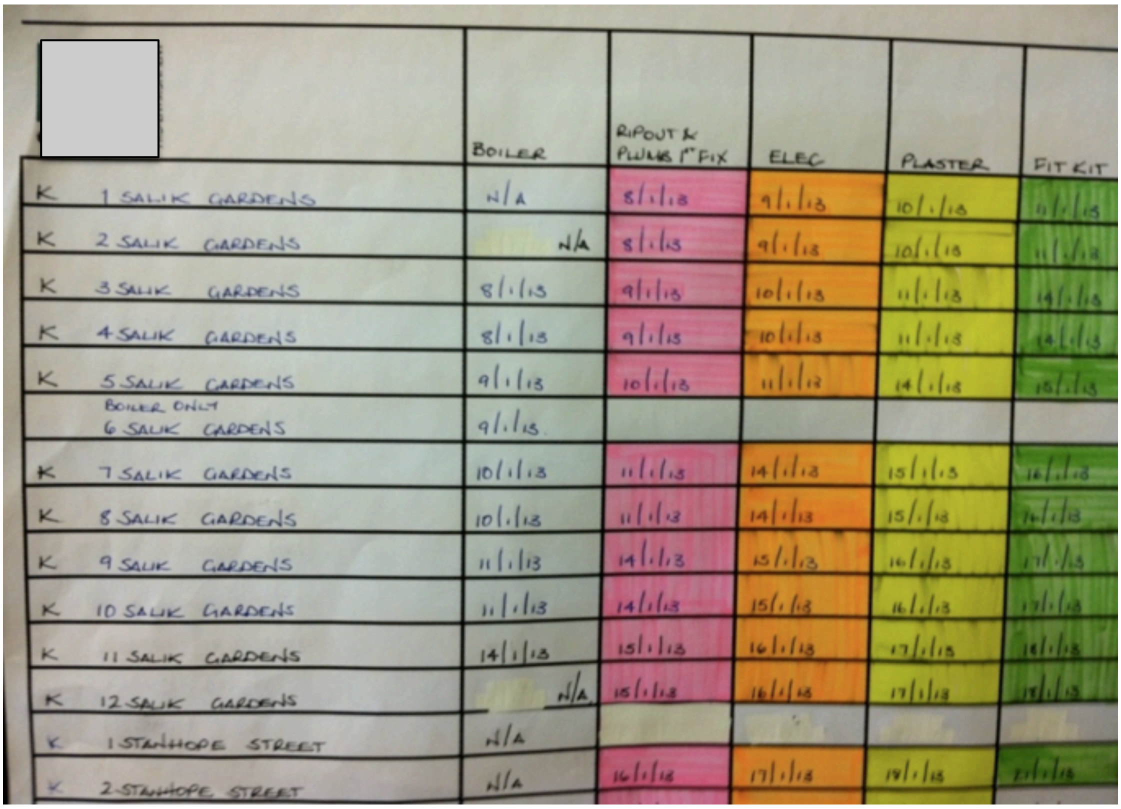

Figure 17 – A production plan at the site office

As shown in Figure 17, the table serves as a production plan for the entire refurbishment scheme and it is also used as progress sheet. The site manager uses colours to indicate which tasks have already been done. Based on this plan, the site manager develops a production plan for the week. In this regard, he said that there is no negotiation with subcontractors, i.e. he tells the subcontractor what he wants and if the subcontractor is not able to do the job, he gets somebody else. In addition, there are no monetary incentives in place to foster productivity. The weekly plan is displayed on the wall at the site office (Figure 18) and it is also communicated to foremen and subcontractors through a formal document (Figure 19).

Figure 18 - Weekly plan displayed on the wall at the site office

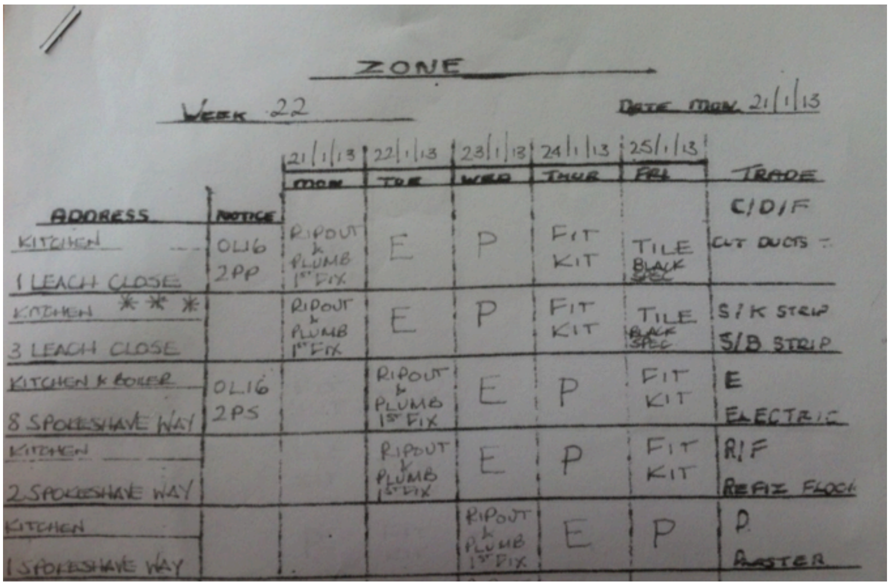

Figure 19 - Weekly plan sent to foreman and subcontractors

The site manager circulates the weekly plan to subcontractors every Monday morning. Also, design drawings (e.g. electrical, plumbing, kitchens) are provided for the tasks scheduled for the week. In order to ensure the accomplishment of the weekly plan the site manager and the TLO visit the properties on a daily basis. According to the site manager, usually 100% of the planned tasks are completed at the end of the week. He said this is because he monitors the work progress daily in order to be able to get the project back on track straight in the day after if necessary. Also, the TLO and the foreman are also constantly visiting the houses to check progress of works.

The foreman works closely with the operatives on site to make sure the works are being done up to the standard set by the housing association and to ensure the accomplishment of tasks assigned in the weekly plan. The site manager assists the foreman by providing whatever information he needs to keep the crews working continuously. He is also responsible for managing health and safety, workforce, programme, and quality issues. The TLO is responsible for dealing with any sort of issue from the tenant’s side and to make sure communication has been done appropriately, namely, tenants are fully aware of what is going on in their houses.

4.2.2.1.3 Typical problems in refurbishments of houses

The typical problems found in refurbishment of houses in the context of a housing association are described below. This information was gathered through interviews, documental analysis, and non-participant observations of meetings and works on site.

4.2.2.1.3.1 Tenants

A number of problems can stem from the tenant side, for example, tenants not being available at certain dates, forgetting to supply the keys to allow workers to work, or simply not showing up as agreed. Also, there are situations where tenants change their minds in terms of the scope of works or specifications that have been agreed with the housing association, for instance, tenants demand extras requests or design changes late in the process, i.e., when works on site have already started or when they are close to completion. Finally, in some cases, it is necessary to prepare documentation in different languages to communicate with tenants from different cultures.

4.2.2.1.3.2 Communication or lack of understanding

Problems related to communication or lack of understanding can be noted in two instances. Firstly, it refers to the communication between the housing association and the subcontractors. The housing association sets the specifications at the outset during the initial meetings. These meetings intend to specify to the contractors and consultant what works need to be done, what material should be used, the quality of the work, standards, and working times. In summary, to be made aware of what the client actually wants to achieve at the end of the programme. Uncertainties at this point on what kind of solutions or specifications should be adopted in a certain case, e.g. inaccurate or incomplete design brief, or lack of details, can lead to problems downstream in the process, such as late design changes, hence driving alterations in cost or/and time.

Secondly, it refers to the communication between the contractor's manager and the site personnel. As part of the preplanning process, managers of the housing association provide instructions to the contractors on how they should deliver the project, i.e. what is expected from them. This refers to practical guidelines such as the need for making contact with tenants prior to any service being carried out on site, how long in advance the tenant should be informed about an appointment, and how to protect tenant's belongings. This information is provided during the initial meetings, but when it gets to site level those instructions tend to get diluted, especially in the case when it is a new contractor. Therefore, problems related to communication can result in a lack of compliance from operatives to the basic procedures on site, such as making sure dust sheets are in place to avoid damages to tenant's belongings, using a badge to identify themselves, handling materials accordingly, workers turning up without notice, or even with notice, but not saying what kind of works they are going to conduct on site.

4.2.2.1.3.3 Variability

Variability is another issue faced during the refurbishment of houses. It refers to unforeseen works (e.g. defective wall) and to variations in the quantity of works that need to be done. Such variations are likely to influence the time and cost planned for the refurbishment. According to a project manager, plastering is one of the most variable things since it depends on the building condition, making it hard to quantify time and cost accurately before the plasterer starts a job. This was confirmed by the workers on site, who said that the cycle time for plastering can vary due to the different kitchens' characteristics, for instance, number of holes left by electricians on ceiling and walls, and can also take longer when they need to skim the whole ceiling when an Artex[18] finishing is found.

4.2.2.1.3.4 High level of work in progress and difficulty to synchronize crews

This problem was not mentioned during the interviews, but it was observed during the site visits and through the analysis of production plans. It refers to the period of time in which a given house remains void (i.e. no crews on site) even when there are still works to be done. For example, a closer look at the planning parameters used by the contractors (Table 16) reveals that the refurbishment is planned to use only part of the time available for a typical working day (i.e. eight hours). For instance, in the first day only half day is assigned for the crews to work, hence leaving work in progress (i.e. kitchen is unfinished) until the next crew come in to work in the following day. Such period of time when the house is with work in

[18] Artex is a surface coating used for interior decorating, most often found on ceilings, which allows the decorator to add a texture to it. The name Artex is a trademark of Artex Ltd., a company based in the United Kingdom. This term is often used to refer to similar products from other manufacturers (Source: Wikipedia).

progress (with no works underway) might become even longer when actual cycle times are shorter than what was planned. This was observed during the site visits (Table 17) for several items of work (e.g. electrics, tile kitchen, decoration 2nd phase, handover).

According to contractors, the work in progress is due to the nature of works (i.e. variability in terms of scope of works, constrained space) and the difficulty to synchronize crews which was noted by manager who said that "you cannot maintain a crew outside waiting a crew coming out in order to they come in". Indeed, these are important issues to be considered if one wants to improve efficiency in production. However, it is argued that such a high level of work in progress remains a relevant problem, especially in a project context where most of the houses are occupied during the refurbishment works.

4.2.2.1.3.5 Lack of formalisation of problems

No formal document was identified for registering the problems encountered on site. For instance, during the site visits it was observed two cases of rework that caused disruptions in the workflow. In the first case (Figure 20), a gas pipe was misplaced behind a kitchen unit, so the plumber had to get back on site to fix the problem.

Figure 20 – Gas pipe relocated due to inaccurate drawing

Similarly, in the second case, a light switch was fitted in a wrong position (Figure 21), then the electrician had to come back to relocate the socket to let the ceramic tiler finish his job. The switch had to be lifted up to let the ceramic tiles align with the worktop edge. In the latter case, lack of information caused the rework as the electrician did not have a view on the drawing to indicate the height of the switch. The gas pipe relocation was due to an inaccurate drawing.

Figure 21 – Light switch (top right) fitted in a wrong position

Despite the disruptions in the workflow, the contractor did not formalise the problems observed and, as a result, no improvement action was taken to tackle such issues. The manager of the housing association said that these reworks do not cause any financial problems to his organisation since they do not pay for such reworks. Nevertheless, it is argued that such problems can interfere with the work performed by other trades, hence causing delays in the construction programme.

4.2.2.1.3.6 No input from subcontractors in the production planning

The communication between planning and production is done in a one-way fashion. The elaboration of the production plans is up to the site manager who works for the main contractor. The subcontractors do not participate in the production planning process. As reported previously, the work assigned in the weekly plans is not negotiated with subcontractors and if these disagree on the tasks assigned in the plan then the site manager gets somebody else to do the job.

4.2.2.1.3.7 Lead time variation for the same type of refurbishment

Although working in similar projects, i.e. refurbishment of kitchen with the same scope of works, the contractors consider different sequences and cycle times in their production plans. Such differences result in distinct lead times for the same type of refurbishment as can be observed in Table 16.

4.2.2.1.3.8 Other problems considered as minor issues

Minor issues refer to problems that happen occasionally, but affect the workflow on site. For instance, design not being done correctly (hence causing rework or delays), location of the houses (waste of time to move from one house to another), lack of materials (delivery delays) or suppliers delivering wrong materials on site (e.g. kitchen kits), and bad weather.

4.2.2.1.4 Best practices

4.2.2.1.4.1 Structured and collaborative preplanning process

The collaborative meetings set at the outset of the refurbishment process (e.g. pre-contract and kick start meetings) help to reduce uncertainties related to design, construction, and also concerning to tenants, thus contributing to avoid disruptions on site. It makes clear for the consultant and contractors what the housing association expects from them in terms of both the technical details of the refurbishments (e.g. materials specifications, quality standards, etc.) and the non-technical aspects involved in the projects (e.g. rules of communication between contractors and tenants, expected behaviour of workers on site, tenant's supportive needs, etc.). In a project context where the majority of houses are occupied, such an approach is essential for ensuring a continuous workflow on site as well as tenants' satisfaction.

4.2.2.1.4.2 Effective and constant communication with users of the building

The housing association seeks to maintain a close relationship with tenants in order to avoid any kind of miscommunication as well as ensuring a smooth workflow on site. To this end, several interaction channels are in place for dealing with tenants. Managerial positions are created and processes are set to support an effective communication. For instance, specific roles such as the Property Services Coordinator (who works for the housing association) and the Tenants Liaison Officer (who works for the contractor) are in place to make sure tenants are satisfied with the services provided. They can also report any problems to the Housing Management Team and have their preferences taken into account through consultations carried out by the core project team. In addition, the customer induction information, also known as customer information pack, is another example of mechanism used to communicate with clients. It contains details concerning the construction phase (e.g. scope and sequence of works, expected lead times, complaints and handover procedures, etc.) and is provided to tenants before works are due to start on site, so they know exactly what to expect from the contractor and how to proceed in case of any deviation that emerges along the way. It is worth mentioning that this document is available in several languages since the clients of the housing association come from different countries.

4.2.2.1.4.3 Maintenance of essential services in the existing building

It was observed throughout the study that essential services in the existing building such as heating, water and electricity supply, and kitchen's appliance (e.g. sink, oven, fridge) were kept running properly by the contractor at the end of each working day. In a project's context where the building remains occupied during construction works, this is extremely necessary.

4.2.2.1.4.4 Daily site visits

The routine of monitoring the works on site on a daily basis is considered vital for the accomplishment of the production plan in a refurbishment project. The site manager and the tenant liaison officer visit the houses regularly to check progress and quality of works. The visits are also important to ensure crews work continuously and tenants are well informed about the refurbishment progress.

4.2.2.1.4.5 Long-term relationship with skilled people in refurbishment projects

Two contractors work for the housing association. Both of them have been working in the refurbishment sector for over 40 years, so they have got considerable experience on how to carry out works in this context. Besides, the housing association seeks to establish a long-term relationship with its partners. It is the third year that the same contractor is working for the housing association, so he is familiar with the system in place.

4.2.2.1.4.6 Use of visual aids to improve communication and decision making

Visual aids are used to help residents to make decisions regarding the materials that will be installed in their houses. This refers to choice menus containing pictures of materials that are going to be installed in the kitchens instead of presenting material specifications only in a written format. In addition, the use of small prototypes such as mini doors are also helpful to communicate with clients in order to promote agility in the decision making process. Another example of visual aid used to improve communication, is the adoption of a color-coded progress sheet (Figure 17), which is used to indicate visually the planning status.

4.2.2.1.4.7 Standardisation of materials' specifications

According to managers of the housing association, the standardisation of materials' specifications utilised in the refurbishments helps to reduce design-related uncertainties and so facilitates the consultation process carried out as part of the customisation offered to tenants as well as the procurement process.

4.2.2.1.5 Opportunities for improvement from a lean perspective

4.2.2.1.5.1 Compress lead time

Although the lead time for refurbishing a kitchen has not been mentioned by the interviewees as a problem, it is argued that it could be compressed. As can be noted in Table 17, the level of work in progress is high since there are several days during the refurbishment in which the house remains empty, after an operative finishes his job until the following day when the next trade comes on site. Furthermore, during on site observations it was noted that the cycle times of some construction processes are overestimated (Table 17). For instance, decoration (2nd phase) took five hours instead of eight as planned. Likewise, the handover took only three hours rather than eight.

The time compression should be seen as the basis for continuous improvement since its pursuit leads to the elimination of wastes such as movement and waiting time. Besides, it is particularly appropriate for this project context because it would minimize tenants' annoyance due to hassle in one of the most used area in a house, i.e. the kitchen.

It is worth mentioning that the advantages and disadvantages of compressing the lead time should be understood from the perspective of all project participants, i.e. tenants, housing association, contractors, subcontractors, consultant, and suppliers. On this regard, further work is necessary to identify the enablers and barriers to achieve such time compression as well as understanding its impact on the refurbishment's scheme as a whole.

The following managerial tools and techniques are suggested for supporting the implementation of the proposed improvement: Production System Design, Last Planner System, Line of balance, and Multiskilling.

4.2.2.1.5.2 Spend more time at the front end to sort out the brief

In order to enable a smooth workflow on site as well as compressing the refurbishment lead time the uncertainties related to design should be reduced as much as possible. Despite the collaborative preplanning process set by the housing association, it was noted that the briefing process could be more prescribed and better prepared beforehand. It is primary to be aware of clients' exact requirements in order to avoid late design changes and extra costs due to such changes. To this end, it is recommended that more time is spent at the front end to organise the briefing (design issues) prior to entering the tender phase. In addition, the choice menus used for consultations should be sent to tenants before the housing association go to visit a property in order to give them more time to think about choosing the design, to talk to their family, especially because a kitchen is one of the most important features in the house. It is contended that this practice can help to avoid late design change requests, hence reducing disruptions in the construction workflow and schedule delays.

The following managerial tools and techniques are suggested for supporting the implementation of the proposed improvement: Standardisation, Mass customisation, and Visual Management.

4.2.2.1.5.3 Promote collaboration in the production planning process

The adoption of a collaborative production planning process is recommended for improving the performance of works on site. The engagement of subcontractors can help to address problems of miscommunication or lack of understanding mentioned earlier, thus avoiding unnecessary issues with tenants. Yet, it is argued that the level of commitment to execute an assignment is higher when the team involved in its execution participate in the creation of the plan.

Last Planner System is suggested for supporting the implementation of the proposed improvement.

4.2.2.1.5.4 Improve control at the hand-off between trades

This recommendation aims at ensuring that the quality of work handed over to a given subcontractor is up to the standards set by the housing association. It is argued that it would help to avoid reworks such as the ones identified in the study (e.g. relocation of gas pipe and light switch). It is also contended that such practice would help to reduce the number of snags to be done at the end of the refurbishment process, hence contributing to lead time compression.

Last Planner System and Standardisation (i.e. use of work standard procedures) are suggested for supporting the implementation of the proposed improvement.

4.2.2.1.5.5 Improve transparency on design drawings

During the observations conducted on site, minor reworks due to the lack of details on the drawings were noted. For instance, the electrician did not have a view on a drawing to indicate the height of the switch, so he positioned it incorrectly therefore making impossible for the tile fitter to finish his job. As a result, the electrician had to redo the job (lift up the switch) in order to let the next trade complete his work. Managers of the housing association commented that the electrician should know details such as the height of the switches as they are standard for every house, but it is argued that more detailed drawings could help to avoid disruptions and reworks like the ones observed during the study.

Visual management is suggested for supporting the implementation of the proposed improvement.

4.2.2.1.5.6 Standardise work sequencing and cycle times

Despite working on similar projects, contractors adopt different sequence of works and cycle times. For instance, it was verified during the study investigated that one contractor prefers to execute decoration prior to flooring whereas the other chooses the opposite. Also, while one contractor plans eight hours for the handover and seven for plastering the other estimates only two and four hours to the respective works. Since the refurbishments carried out are similar, the standardisation of such parameters is recommended in order to enable the creation of a reference basis for site personnel training and a baseline for continuous improvement. Besides, contractors could work collaboratively with the purpose to identify the best way to achieve a high quality and safe delivery within cost and time constraints.

Standardisation (i.e. use of work standard procedures) is suggested for supporting the implementation of the proposed improvement.

4.2.2.1.5.7 Develop a culture of continuous improvement

The act of addressing problems consistently is essential to develop a culture of continuous improvement. During the development of the study, it was noted that the problems detected on site were not formalised (e.g. reworks due to inaccurate and incomplete drawings). It is argued that the lack of formalisation of problems hinders improvements in a consistent way. Therefore, the implementation of a production planning and control system, properly designed for rapid learning through problem solving, is suggested. Such an initiative aims at avoiding the repetition of the same problems in distinct projects. Yet, the problems identified along the refurbishment schemes could be used for training purposes. The use of additional practices, such as benchmarking and collaboration between project participants, can also foster a culture of continuous improvement. It is argued that such practices can help to improve the entire refurbishment process from preplanning and building surveying to production and handover phases.

Last Planner System, A3, and Benchmarking are suggested for supporting the implementation of the proposed improvement.

4.2.2.1.6 Inputs for developing the artefact

The main contributions of the first empirical study for the development of the artefact proposed in the thesis are described as follows:

- Findings from the study confirmed what was found in the literature, namely, the management of refurbishments projects involve three main parts: a) the existing asset, b) the works on site, and c) the operations in the existing building;
- Empirical evidence confirmed also that those three parts are related to each other, i.e. a thorough building surveying is essential for reducing uncertainties related the existing asset, thus enabling a better design quality as well as a continuous workflow on site. Likewise, preplanning and an effective and constant communication with tenants is primary in this context as tasks are carried out in an occupied building;
- The typical problems identified throughout the study served as reference basis for the proposition of countermeasures in a lean sense;
- Managerial tools and techniques aligned with the lean management approach have been suggested as candidate solutions for supporting the implementation of the proposed countermeasures. This addresses two key issues spotted during the literature review (section 3.1.2.3): the lack of indication of managerial tools and techniques to support the implementation of guidelines for improving the management of refurbishment projects and the lack of theory for underpinning managerial practices;
- Seven best practices were extracted from the study. It is argued that they can be transferred to other refurbishment contexts with similar characteristics as candidate solutions for improving the management of works on site;
- In terms of new knowledge that emerged from this empirical study, the author calls attention to the topics not well investigated in previous studies such as the importance of compressing lead time, minimising work in progress, improving process transparency, standardising work sequencing, and developing a culture of continuous improvement.

4.2.2.2 Empirical study 2 – Refurbishment of banks

The second empirical study was conducted in partnership with a banking organisation in Brazil. It took place in June 2013. Information was collected mainly through semi-structured interviews and analysis of documents used in the management of construction of refurbishments. A visit to a refurbishment site was conducted, so direct observations could be also made. Similarly to the first empirical study, the main criterion for selecting the people to be interviewed, as well as the documents analysed, was their connection with the management of construction in refurbishments. The researcher conducted a meeting along with representatives of the bank in order to validate the research findings. Further details on the sources of evidences utilised throughout the study are presented in Table 18, Table 19, and Table 20.

Table 18 - List of interviews carried out in empirical study 2

Interview	Interviewee's position	Organisation	Job functions
1	Architectural Project Manager	Bank	Responsible for project and space planning management
2	General Project Manager Infrastructure	Bank	Overall responsibility for the execution of infrastructure projects, including production and financial planning and control of refurbishment of infrastructure areas, logistics, and management of stakeholders
3	Design Manager Infrastructure	Bank	Responsible for coordinating design of structural projects, MEP, HVAC, automation, and security systems
4	Senior Project Manager Construction	Bank	Overall responsibility for the execution of construction projects, including production and financial planning and control of refurbishment of branches and corporate buildings, logistics, and management of stakeholders
5	Site Manager	Bank	Responsible for supervising construction sites, managing contractors, health & safety, quality, and programme
6	Consultant	Consultancy A	Overseeing effective delivery of refurbishments on behalf the client (bank), supervises the work developed by the contractors in terms of quality, cost, and time. Develops design in some projects upon request
7	Consultant	Consultancy B	Overseeing effective delivery of refurbishments on behalf the client (bank), supervises the work developed by the contractors in terms of quality, cost, and time
8	Procurement manager	Contractor A	Procurement of material and labour
9	Technical Coordinator	Contractor A	Coordination of MEP services
10	Project Manager	Contractor A	Responsible for managing health and safety, workforce, programme, and quality on several refurbishment sites
11	Electrical Engineer	Contractor B	Management of HVAC and MEP services
12	Architect	Contractor B	Responsible for supervising construction sites, including subcontractors, health & safety, quality, and programme
13	Technical Director	Contractor C	Management and delivery of refurbishment schemes for clients, perform tasks such as procurement, production planning and control, and management of subcontractors
14	Technical Director	Contractor D	Management and delivery of refurbishment schemes for clients, perform tasks such as procurement, production planning and control, and management of subcontractors

Table 19 - Observations carried out throughout the study

Observation	What was observed	Place where the observation was conducted
1	Refurbishment works	On site (refurbishment of a corporate building)

Table 20 - List of documents assessed during the study

Document	Title	User	Information displayed in the document
1	Meeting minutes	Bank, Contractor, Consultant	Project deadlines, pending issues, project constraints, dates for material delivery, list of drawings issued by the designers
2	Progress report	Bank	Construction programme status (planned vs. actual)
3	Photo report	Bank, Contractor, Consultant	Pictures taken on site showing the services already finished by the contractor as well as the refurbishment works underway
4	Production master plan (bar charts)	Contractor, Consultant	List of activities, specification of predecessors and successors, duration, planned dates (start/end)
5	Production control	Contractor, Consultant	List of subcontractors, list of activities, planned dates (start/end), and actual dates
6	Short term production plan	Contractor, Consultant	List of activities planned for the weekend and night shifts
7	Production plan for temporary works	Contractor, Consultant	List of works that enable construction of, protect, support or provide access to the permanent works
8	General guidelines for working in occupied buildings	Contractor, Consultant	Building regulations (cleanliness, safety procedures, working times, material storage), contact details
9	Bill of quantities	Contractor, Consultant	Scope of works, quantities of work, cost per unit (material and labour), overall cost
10	Health and safety inspection report	Contractor	Causes of health and safety issues and actions to be taken
11	Health and safety guidelines	Contractor	Provide guidance for workers on health and safety regulations
12	Health and Safety training form	Contractor	Register the types of health and safety training topics provided for each employee

Next, the characterisation of refurbishment projects carried out in the context of a banking organisation, the production planning and control system used by the bank and its partners (contractors, consultants), and the typical problems faced during the construction phase are presented. Then, the best practices identified though the study along with the opportunities for improvement from a lean perspective are described.

4.2.2.2.1 Characteristics of refurbishments in the context of a bank organisation

The bank investigated in this study is one of the largest banks in the world. To support its operations, thousands[19] of people work in thousands of buildings (including branches and corporate buildings) located in Brazil and also overseas. In this context, an appropriate space planning along with the provision of a robust infrastructure in terms of engineering (e.g. information technology and security systems) are needed to support the business

[19] The number of people and buildings are not added to the text due to confidentiality issues.

needs. In addition, the facilities owned by the bank have to be maintained, therefore demanding constant refurbishments. The coordination of those projects is up to a project team that works for the bank. This team is divided into four main divisions (architectural, infrastructure design, infrastructure projects, and construction projects) that collaborate with each other to provide the technical support needed for delivering the projects developed by the bank. The main objectives of this team is to keep the operations running smoothly at minimum cost and preserve the image of the bank by making sure that all physical assets owned by the bank are homogeneous in terms of corporate visual identity. There is also a project management office and a procurement department within the bank. The latter is responsible for the acquisition of project resources (material, equipment, and services) and the former for monitoring the status of on-going projects in terms of time, cost, and quality. A project director, responsible for overseeing the work developed by all those departments, completes the team assembled by the bank for managing their construction projects. Yet, there are also external companies that participate in the delivery of refurbishment projects. They include several small or medium size contractors that are responsible for carrying out works on site, consultants who acts on behalf of the bank overseeing the works developed by the contractors, and also subcontractors that work for those contractors.

4.2.2.2.1.1 Types of refurbishments

There are two types of refurbishment in the context of a bank, namely, branches and corporate buildings. Branch refers to a retail location where the bank offers services to its customers. There are thousands of branches scattered all over the country and overseas. The corporate buildings comprise the properties owned by the bank that are used to accommodate people and equipment needed for supporting business operations. For example, there are buildings used as the bank headquarters, call centres, administrative centres, etc. A common feature shared by those two types is the short time available for construction. Such interventions have to be carried out as quickly as possible to avoid hassle to customers and disruptions in the bank’s operations. Another mutual characteristic is the necessity to work on occupied buildings that remain fully operational. In this context, temporary structures are sometimes needed to safeguard users and business activities. Further details about the features of each type of refurbishment are described as follows.

Refurbishment of branches is generally driven by the need to update infrastructure systems and/or internal layout as well as standardising the corporate visual identity. Time is a major constraint in these projects because there are strict deadlines to be met for the opening of refurbished branches. The construction phase of a refurbishment in a typical 400 square meter branch takes approximately 45 days. The standardisation of design in terms of layout, furniture, material specifications (e.g. flooring, ceiling, lighting, etc.) and even construction systems (e.g. foundation and wall types) is a noteworthy initiative. It should be noted, however, that such standardisation is not always possible due to the distinct characteristics of the buildings used as branches all over the country. The short time allowed for the refurbishment coupled with the need for keeping the branch in operation requires that crews work mostly at night and during the weekends. Approximately 80% of works on site are conducted out of the bank working hours.

Refurbishment of corporate buildings involves the modification of internal layout to support bank operations, for example, the conversion of an office area into a distinct operational use (e.g. turn an office into a call centre), the retrofit of buildings with the purpose to improve energy performance, and also the refurbishment of infrastructure areas. The latter refers to works carried out to physical spaces designed to house infrastructure equipment needed for supporting banking services (e.g. data centres). Basically, these projects aim at keeping bank operations running smoothly by upgrading and maintaining the existing infrastructure systems (e.g. data processing, security, automation, etc.). They present a higher level of complexity in terms of design in comparison to the other types of refurbishments. Time is also an important constraint to be considered in the refurbishment of corporate buildings. This is mainly due to the interference that such projects might cause to building users and operations. However, differently to what is found in branches, in corporate buildings the project deadlines are more likely to be negotiated if necessary. The construction lead time varies according the scope and complexity of works, for example, a refurbishment of an infrastructure area might take just one weekend, whereas a retrofit of an entire building may last months. Yet, there are examples of refurbishment of corporate buildings that takes more than one year. In projects such as alterations of internal layout and retrofits it is more likely to schedule the execution of works during the bank working hours since it might be possible to decant people (i.e. moving them out of the area being refurbished) to other areas in the same building. Nonetheless, even when an area (e.g. entire floor) can be vacated there might be a need to work outside of normal working hours due to noise and dust disturbance caused by construction sites. Finally, it is noteworthy the standardisation of the design in terms of material specifications (e.g. flooring, ceiling, lighting, etc.), especially when retrofits or layout conversions are conducted.

4.2.2.2.1.2 Preplanning stage

The starting point of a refurbishment project in the context of the bank investigated in the study is the development of the design. There are three main phases to be performed in this regard: a) design briefing and scope definition, b) preliminary study and conceptual design, and c) design development. The feasibility appraisal of the project is the main objective of the first phase of the design process, which normally takes five days. Then, the designer has forty days, on average, to develop the second and third phases, which includes carrying out a building surveying, developing the conceptual design, getting feedback from managers of the bank, promoting the necessary amendments, and then submitting the final version for approval. The next step refers to the procurement process, which is performed by managers of the bank and comprises the selection of the contractor, consultant, and the purchase of materials (high volume items) and equipment (high value items). This process might take up to thirty days and precedes the start of works on site. The purchase of minor material items and equipment is up to the contractor hired for the project.

Meetings are held at the beginning of each design phase. Managers of the bank who have some sort of connection to the project (e.g. future users of the area being refurbished) attend those gatherings along with designers and project managers. The main objectives of those meetings are to make sure that the design meets business and users' requirements as well as getting feedback on the design being developed, though at this point contractors are not yet hired and do not participate in the design stage, consequently, they contribute to the analysis of the design when it is completed and not during its development. Likewise, the consultants usually do not collaborate at this phase unless they were hired for that purpose.

Normally, there are no as-built drawings of the existing building available to assist designers on the design development. Yet, when those drawings are available they are usually not accurate. In this context, a preliminary study, which should include a thorough building surveying of the existing asset, is essential to make sure that the decisions made by the designers are based on accurate information.

However, despite its importance, the building surveying is carried out carelessly. The main reason for such negligence is the lack of time and money for conducting a proper building surveying and developing a high quality design. The short time available coupled with the low value invested by the bank for developing the design do not allow an appropriate surveying of the existing asset nor an adequate design study. In some cases the designer does not even go on site to carry out the surveying. Hence, drawings are not well coordinated with the current building situation. Several problems are caused by the lack of a proper understanding of the existing asset such as an ill-defined scope of works, design clashes, and cost overrun due to the high level of extra works carried out on site. Besides, because those design clashes are detected during the construction phase, disruptions in the workflow on site occur frequently and last until the designers correct the design.

According to managers of the bank, time is a key constraint in refurbishment projects, so the design is carried out as quickly as possible to enable the procurement of materials and services needed for starting the project. Another reason that hinders a proper surveying is the need to keep the building in operation without interfering with users. In other words, the inspection of the existing asset is more challenging when the building is occupied.

As soon as the design phase is completed and the budget for the project approved the senior project manager, who is responsible for overseeing the construction phase of several refurbishment projects, set up a kick-off meeting. The aim is to introduce the final version of the design to representatives of operational areas such as operation and maintenance, information technology, security, automation, etc. The team analyses the design and if some inconsistency is found the design is sent back to the designer for the necessary reviews. In this meeting, which is also attended by a management consultant hired to assist managers of the bank in the project supervision, the senior project manager explains the role of each participant in the project and lists the constraints for the execution of works on site based on prerequisites voiced by the attendees. For example, the automation department might demand a temporary structure in order to avoid disruption in the business operations. Yet, a preliminary version of the construction programme is also shared with the team so they can assess whether the plan is doable or not. It should be noted that the contractor does not attend this meeting since it is not hired yet at this point unless the project refers to special situations, e.g. complex projects.

4.2.2.2.2 Existing production planning and control system

The overall management of construction in refurbishment projects is up to two senior project managers. They work along with a team of architects and engineers who also work for the bank on the supervision of several projects carried out concurrently[20]. Basically, they assist the two senior project managers by overseeing the work conducted by contractors in terms of quality, time, cost, and health and safety. As mentioned before, there is also an external project team assembled for managing each refurbishment project. Basically, it consists of a management consultant, a contractor, and subcontractors.

The first step in the existing production planning and control system is the preparation of a preliminary version of the construction programme. This plan is set up by the senior project manager and is based on his experience acquired over time in past projects. At this point, it is not a detailed plan yet. On the contrary, it displays only the total duration set for the project as well as the milestones set for the main activities (e.g. start and end dates of installation services). As mentioned in the previous section, this plan is introduced initially to representatives of several operational areas within the bank and it is shared later with the contractor prior the start of works on site for validation, i.e. to assess whether the deadlines proposed are doable from an operational perspective. The final version of the construction programme, also known as master plan, may or may not be broken down in a detailed plan. This decision depends on the type of refurbishment being considered, namely, if it refers to a project with short duration and low level of technical complexity (e.g. refurbishment of a typical branch) then the master plan is utilised as the main tool for controlling the construction phase. Conversely, if it refers to projects with long lead times (e.g. refurbishment of an entire building) or high level of technical complexity (e.g.

[20] To give an idea on the amount of construction projects carried out simultaneously in the bank, eighty projects were being managed by just one general manager and his team of six managers at the time this study was conducted.

infrastructure renovation projects), then a detailed plan is devised by the contractor with the assistance of the consultant. The level of details is extremely high (i.e. the construction programme may reach more than a thousand lines), which makes the review of the plan a laborious and time-consuming process. The contractor updates the plan with the assistance of the consultant on a fortnightly basis. Basically, this plan is utilised by the project team to determine the start date of each activity. It serves also as the main reference for controlling the project, namely, if a delay is identified for a given activity then action is taken (e.g. speed up execution by hiring more workers, working overtime, or changing the sequence of works on site) to put the project back on track.

Despite the differences aforementioned, the managerial practices used in those distinct types of refurbishments are similar. For example, in all projects a weekly meeting involving project participants (e.g. contractor, subcontractors, consultant, project manager, and also representatives of the bank such as operation and maintenance personnel) is set up on site for assessing construction progress, deviations from the planned schedule, and potential changes in the scope of works. Yet, the attendees discuss the constraints (e.g. material, prerequisite work, design drawings, etc.) related to the project. Additional issues addressed in this meeting include health and safety concerns, site logistics (e.g. material storage), and site organisation and cleanliness. A meeting minute is generated as the main output of this meeting. Basically, it summarises the main topics discussed throughout the meeting such as pending project issues, expected dates for material delivery and design approvals, revised construction programme dates, and list of valid drawings.

In addition to the master plan and weekly meetings, there is also a daily report. It refers to a notepad utilised by the contractors to register the progress of activities on site, including the problems identified throughout construction as well as the reasons for not accomplishing the planned activities. Moreover, it contains the unforeseen situations encountered during the refurbishment (e.g. existing building structure different than what is found in the design drawings). Despite being an important record, the information gathered through this report does not necessarily lead to improvements. Evidence of such a problem is the issue related to the lack of a preliminary building survey, which occurs repeatedly in several projects. Furthermore, the consultant carries out site visits regularly. As a result, a photographic report is produced to inform the status of works on site to managers of the bank. This is presented along with a written document that reports the progress of activities as well as the problems identified during construction and suggested improvement actions.

It is worth mentioning the special planning procedure utilised for carrying out the critical activities. These refer to some activities that present a high level of interference with the operations in the existing building and for that reason demand a distinct programme scheduled for non-working hours (e.g. weekends or in the evening). This procedure states that pre-inspections should be conducted prior to the start of the activity for analysing what can be done to allow an efficient execution. Those assessments are conducted by a multi-disciplinary team formed by representatives of every sector affected by the critical activity (e.g. building operation and maintenance personnel, contractor, subcontractors, etc.). In summary, it is teamwork that seeks to anticipate potential problems, as well as finding the best way to accomplish a task in order to avoid disruptions to business operations.

The information generated by the contractor and the consultant is analysed by the project manager and then summarised into a PowerPoint presentation. It refers to a visual control that reports the progress of the project by indicating the status of several activities in a simplified format (Figure 22 and Figure 23). The visual controls enable an overall analysis of all projects developed by the bank.

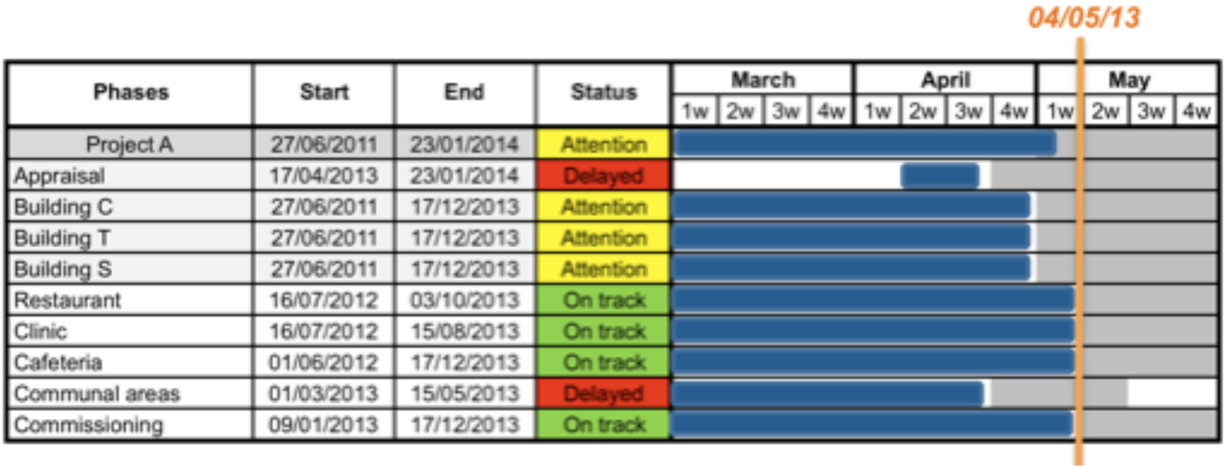

Figure 22 – Chart used to track progress on a project

	Description	Plan	Actual	End Date	Status
2nd Floor	Structure	98%	98%	Done	
	Masonry	98%	98%	Done	
	Finishings	73%	71%	01/10/2013	
	Commission	0%	0%	18/10/2013	
1st Floor	Structure	98%	98%	Done	
	Masonry	98%	98%	Done	
	Finishings	73%	72%	01/10/2013	
	Commission	0%	0%	11/10/2013	
Ground Floor	Structure	98%	98%	Done	
	Masonry	41%	25%	30/09/2013	
	Finishings	10%	5%	21/10/2013	
	Commission	0%	0%	28/10/2013	

Status	on track	delayed	done	to be started	attention
Indicator					

Figure 23 - Planned versus Actual Project Tracker

The visual controls, which are generated for each refurbishment project, are verified by the senior project manager and then sent to the project management office. This department collates information from all sites and presents an overview on the progress of all projects to the project director. For example, out of eighty projects underway, sixty are on track, ten are delayed, and ten have been cancelled. This summary is important because there are several divisions within the bank working in different projects so it is essential to keep them updated about the progress of every project.

4.2.2.2.3 Typical problems in refurbishment of banks

The typical problems identified in the refurbishments investigated in this study are described as follows. This information was gathered through interviews, documental analysis, and observations on site.

4.2.2.2.3.1 Poor building surveying

The lack of a proper understanding of the existing building is a major issue in refurbishment projects resulting in a myriad of problems both in design and construction as noted in this study. The poor building surveying process was considered as the root cause of typical problems such as poor design quality, ill-defined scope, design-related rework, disruptions in the workflow on site due to design clashes, and also cost overrun.

4.2.2.2.3.2 Late involvement of stakeholders in the design stage

Representatives of operational areas within the bank such as operation and maintenance, information technology, security, automation, etc. join the project only at the kick-off meeting when the design is already finished. This late involvement might cause design rework should the operational personnel find inconsistencies in the design. This can delay the start of the project as design alterations take time to be processed by the designers.

4.2.2.2.3.3 Ill-defined scope of works

This problem was mentioned by several interviewees as one of the main reasons for design-related rework, disruptions on site, and cost overrun. Since there is not enough time for defining the scope of works properly during the design phase, managers of the bank who demand the refurbishments end up changing the scope during the construction phase. The problem is that those alterations normally take time to be resolved by the designers, hence interrupting the construction workflow. This is detrimental to contractors as normally they end up working overtime or have to hire more workers to speed up the construction pace in order to meet project deadlines.

4.2.2.2.3.4 Repetition of the same errors across projects

Despite the mechanisms utilised for registering problems and proposing improvements such as meetings and reports, it was noticed the repetition of the same errors across projects. For example, the lack of a thorough building surveying and its associated issues such as poor design quality, ill-defined scope, design-related rework, disruptions on site, and cost overrun, can be considered as chronic problems in the refurbishments of the bank.

4.2.2.2.3.5 Unforeseen site conditions

In general, this is a feature that can be considered part of the nature of refurbishments, but in the context of the bank it is aggravated by the lack of a proper building surveying. Differing site conditions can cause design-related rework, disruptions in the workflow on site until the design is revised, schedule delays, and cost overruns.

4.2.2.2.3.6 Delays in material delivery

It was mentioned during the interviews that some suppliers struggle to meet the deadlines for delivering materials on site. According to managers of the bank, this problem is more likely to occur when it refers to materials obtained from abroad (e.g. electricity generator, air-conditioned equipment) due to customs clearance delays, although it can also happen to materials acquired locally as local suppliers are not always reliable.

4.2.2.2.3.7 Lack of integration between design, construction, and operations

The sequence of assembly of a given system (e.g. electrical, automation) defined in the design stage is not integrated with the configuration of the existing system encountered in the building. As a result, temporary structures might be necessary to safeguard business operations. These, in turn, are likely to increase project cost and cause schedule delays.

4.2.2.2.3.8 Use of an inappropriate production planning and control system

The production planning and control system adopted by the bank is not suited to deal with refurbishment projects. In terms of planning, it is safe to say that the use of a highly detailed plan for managing production of uncertain, quick, and complex projects such as refurbishments is not appropriate. This is because such approach assumes, wrongly, that complex projects can be represented through simple sequential links. Moreover, it rests on a deterministic model that neglects the variation intrinsic to refurbishment settings. As a result, constant and time-consuming updates are needed to adjust the plan to the real situation on site. In terms of production control, the use of a reactive model is not effective because it does not ensure a reliable workflow on site as its focus is on output measures, i.e. action is taken only when a problem (e.g. schedule delay) is identified.

4.2.2.2.3.9 No contractor or subcontractor input during design development

Normally, the contractor analyses the design drawings only when these are already finished. This late involvement causes design-related rework and might delay the start of the project. Besides, there is no evidence of participation of subcontractors during the design process.

4.2.2.2.4 Best practices

4.2.2.2.4.1 Standardisation of design features

An important initiative identified during the study was the standardisation of design features such as layout of branches, material specifications, and construction systems. This aims at simplifying the management of the project by reducing the number of suppliers involved as well as improving efficiency on site. Yet, the use of standard materials aims at providing consistency in terms of visual identity of the bank.

4.2.2.2.4.2 Integration of internal clients during the design development

Meetings with the future users of the area being refurbished are held during the design development. The feedback of project's internal clients on the design being developed is crucial to ensure business needs and users' requirements are effectively met.

4.2.2.2.4.3 Early identification of project constraints

The identification and removal of project constraints is primary for enabling a smooth workflow on site. On this respect, it is argued that the kick-off meeting helps to reduce the uncertainties intrinsic to refurbishments. The general project manager and the representatives of operational areas within the bank work collaboratively in the identification of such project constraints. Sadly, contractors and subcontractors do not participate at this point, but this early assessment is still a practice worth mentioning.

4.2.2.2.4.4 Collaborative site pre-inspections

This practice was identified for the particular case of critical activities, i.e. tasks that present a high level of interference with the operations in the existing building. The pre-inspections are instrumental for anticipating problems that would normally be detected only during the execution of works on site. Thus, it is argued that it can help to avoid disruptions in the workflow. Also, the collaboration between companies involved in the job is vital for enabling an effective assessment as well as defining the best way (sequencing) to do a given task.

4.2.2.2.4.5 Visual controls

The use of colour-coded tables for displaying the status of main activities is useful to provide a comprehensive and user-friendly overview of construction projects developed by the bank.

4.2.2.2.4.6 Prototyping

This practice was implemented during the retrofit of a corporate building. Since the project involved a refurbishment of a high-rise building it was decided to use the first two floors as a prototype for developing design solutions. These, in turn, were standardised and implemented later in the rest of the building.

4.2.2.2.4.7 Daily site visits

As mentioned earlier, unexpected site conditions can be considered as part of the nature of refurbishment projects. Such uncertain scenario demands a responsive system to ensure a continuous workflow on site. In this context, the practice of monitoring production on a daily basis is vital to promote agility in decision-making in order to avoid waste of time due to disruptions in the workflow.

4.2.2.2.5 Opportunities for improvement from a lean perspective

4.2.2.2.5.1 Reduce uncertainty both in design and construction phases

In refurbishment projects, a consistent removal of uncertainties is of paramount importance for achieving a high performance both in design and construction phases. On this regard, two main aspects deserve attention. Firstly, it is argued that a thorough building surveying should be conducted prior to works start on site. This practice is very important especially when as-built drawings are not available or accurate as found in the context of the bank. A proper preliminary study will improve the quality of design since designers will base their assumptions on reliable information. It is noteworthy, however, that more time might be necessary for enabling a sound building surveying. Secondly, it is also recommended to shield production against uncertainty through the identification of constraints for every task before they are released to production. Site inspections are instrumental for that purpose, i.e. go and check if it is ready for working. In order to ensure the efficacy of such processes, a collaborative approach is essential, namely, all stakeholders involved in the project should take part in the assessments on site and planning meetings.

The following managerial tools and techniques are suggested for supporting the implementation of the proposed improvement: Production System Design, Last Planner System, and Benchmarking.

4.2.2.2.5.2 Adopt a production planning and control system suitable for the refurbishment context

Several authors in the literature of construction management in refurbishment projects contend that production control systems should match the project context (Sanvido & Riggs, 1991; CIRIA, 1994; Egbu et al., 1996; Egbu et al., 1998). Refurbishments are generally regarded as complex and uncertain projects due to their intrinsic characteristics. In this context, the use of traditional management practices such as the ones identified in the study (e.g. high detailed plans along with a reactive model of control) is not the best option. Therefore, it is argued that such conventional management approach should be replaced by a production planning and control system capable to deal with the complex and uncertain nature of refurbishments.

Last Planner System is suggested for supporting the implementation of the proposed improvement.

4.2.2.2.5.3 Engage the right people at the right time

The early involvement of key stakeholders such as the contractor, subcontractors, and operational areas involved in the project (e.g. maintenance and operation, automation, security, etc.) is crucial for the achievement of better results in terms of design and construction. They should contribute to design development for improving its quality in order to avoid rework due to late design changes. Also, the timely engagement of project parties would help to address refurbishment issues such as the integration between design, production, and operations in the existing building as well as scope definition.

Integrated Project Delivery and Last Planner System are suggested for supporting the implementation of the proposed improvement.

4.2.2.2.5.4 Develop a culture of continuous improvement

As mentioned earlier in this thesis, the act of addressing problems consistently is essential to develop a culture of continuous improvement. The repetition of the same problems across different projects, as noted in this study, is a clear evidence of a flawed management system. Therefore, similarly to the first empirical study, the introduction of managerial practices that promote a culture of continuous improvement is promoted. This refers to, for instance, a production planning and control system properly designed for rapid learning through problem solving, the use of benchmarking and knowledge sharing between project stakeholders. It is argued that those practices can help to improve the entire refurbishment process from preplanning and building surveying to production and handover phases.

Last Planner System, A3, and Benchmarking are suggested for supporting the implementation of the proposed improvement.

4.2.2.2.6 Inputs for developing the artefact

This section presents the main contributions of empirical study 2 for the development of the method proposed in the thesis.

- Typical features of refurbishment reported in the literature such as lack of or inaccurate as-built drawings, short construction timeframes, need to work in occupied buildings that remain fully operational were also identified in the study;
- Similarly to empirical study 1, this study also confirmed findings from the literature, namely, refurbishments projects involve the management of three parts: a) the existing asset, b) the construction tasks, and c) the operations in the existing building;
- Moreover, it has become clear during the study the relationship between those three elements cited above. For instance, there is evidence showing the negative effect that the poor integration between those elements can have in project performance (e.g. the lack of a proper building surveying had a negative impact on the design quality, hence causing design-related rework, disruptions on site, and cost overruns). Also, the initiatives aimed at safeguarding operations in the existing building such as the early identification of project constraints and collaborative site pre-inspections were considered as essential measures to ensure continuous flow of construction tasks;
- The typical problems identified throughout the study served as reference basis for the proposition of countermeasures in a lean sense;
- Managerial tools and techniques aligned with the lean management approach have been suggested as candidate solutions for supporting the implementation of the proposed

countermeasures. It is worth mentioning that this contribution tackles two issues identified throughout the literature review (section 3.1.2.3), namely, the lack of indication of managerial tools and techniques to support the implementation of guidelines for improving the management of refurbishment projects and the absence of theory for underpinning managerial practices;

- Seven best practices were extracted from the case. It is argued that they can be transferred to other refurbishment contexts with similar characteristics as candidate solutions for improving the management of works on site;
- In terms of new knowledge that emerged from this empirical study, the author calls attention to the subjects not well addressed in previous research such as the importance of reducing uncertainty both in design and construction phases, adopting a production planning and control system suitable for the refurbishment context, and developing a culture of continuous improvement.

4.2.3 Cross-case analysis

The purpose of the cross-case analysis is to identify the similarities and differences across the empirical studies. This assessment follows the same structure of the studies. Firstly, the project characteristics along with the production planning and control systems are assessed. Secondly, the typical problems, best practices, and opportunities for improvement are analysed. Thirdly, the insights gained during the development of the studies are presented.

Although situated in different industry sectors, the refurbishment of houses and banks presented more similarities than divergences. One basic difference is the complexity of the design, which is more complex in the context of the bank, than those found in projects developed by the housing association. Another exclusive characteristic of a bank refurbishment is the possibility of conducting works at night and during the weekends. The features commonly shared by those refurbishments, include the need to work in an occupied and operational building, the involvement of several stakeholders in the refurbishment process (this happens regardless the size of the project, i.e. the renovation of kitchen in a small house involved more than ten different stakeholders), the high level of uncertainty due to intrinsic project characteristics (e.g. lack of as-built drawings, unforeseen site conditions), the need to finish the construction phase quickly in order to avoid hassle to users of the building, and the clients' interference (e.g. customisation, late design changes). These characteristics show clearly that refurbishments are complex projects.

Despite the complexity mentioned above, the data gathered in both studies regarding the production planning and control systems, confirmed that traditional management practices are still used for managing construction in refurbishment projects. Evidences of such incompatible management approach include practices such as the use of highly detailed production plans, one-way communication between planning and production, thermostat model of control, the excessive use of buffers in the production plans, the lack of collaboration between project stakeholders during the design development, and the absence of a consistent continuous improvement programme.

The use of such inadequate production management practices led to a number of problems both in design and construction. In the refurbishment of banks, this refers to design-related rework, disruptions in the workflow on site, repetition of errors across projects, schedule delays, and cost overruns. In the refurbishment of houses, the main problems are reworks on site, the high level of work in progress, and as a result long construction lead time.

The identification of typical problems was instrumental for proposing countermeasures in a lean sense. This refers to lead time compression, reduction of uncertainties both in design and construction phases, development of a continuous improvement culture, among others. The adoption of a production planning and control system appropriate for the refurbishment context (i.e. Last Planner System) is the main improvement to be carried out by both organisations as it can be seen as a way of driving other essential changes needed for achieving better project results (e.g. collaboration, learning, and continuous improvement). It is argued that the implementation of Last Planner will help companies to better deal with the variability and uncertainty intrinsic to refurbishment projects.

Several best management practices were also gathered during the development of empirical studies. The standardisation of design features (e.g. material specification, construction systems) along with initiatives for reducing uncertainty (e.g. collaborative site inspections, early identification of project constraints, prototyping) are examples of practices found in both studies. It is argued that those practices can be suggested as candidate solutions for improving the management of construction in refurbishment projects.

Findings from the empirical studies also suggest that in order to be effective in the management of refurbishment works one has to ensure that the existing asset is properly surveyed and the operations in the existing building are taken into account through an appropriate management approach. In terms of surveying the existing asset, two different approaches were identified. In the first study the process of gathering information about the existing building was structured, whereas in the second this was conducted without due attention. Several problems both in design and construction were noted in the latter, hence demonstrating the connection between those parts. Safeguarding users and operations in the existing building was a major concern in both studies. Several best practices were gathered on this regard. These were deemed as essential measures for ensuring a continuous workflow on site.

4.3 Developing the artefact

The literature review and the empirical studies were instrumental for the development of the artefact proposed in the thesis. The former provided valuable insights such as the need of having a theory of production as a reference basis for production management. Yet, it pointed out the importance of recognising the nature of the project in order to devise a proper construction management approach. The empirical studies, in turn, contributed to a better understanding of refurbishments characteristics, including details on the production planning and control systems used for managing the construction phase. Also, they served to indicate the typical problems, best practices, and also opportunities for improvement.

Altogether, those findings and insights shaped the first version of the method proposed in this thesis. The main artefact (i.e. the method) is composed of other artefacts, which are presented in the next subsections. The method itself is described at the end of this section since it would make no sense to introduce an artefact without mentioning its components.

4.3.1 Components of the method

The initial version of the method is a combination of the following artefacts:

- A conceptual model of refurbishment projects;
- A framework for characterising refurbishment projects;
- Candidate solutions for improving the management of construction in refurbishment projects.

Next, the artefacts mentioned above are presented.

4.3.1.1 Conceptual model of refurbishment projects

The conceptual model presented in this section stemmed from two sources: literature review on refurbishment projects and empirical studies. Findings revealed that refurbishment projects comprise and therefore can be conceptualised in three main parts: the existing asset, the construction tasks, and the operations in the existing building (Figure 24).

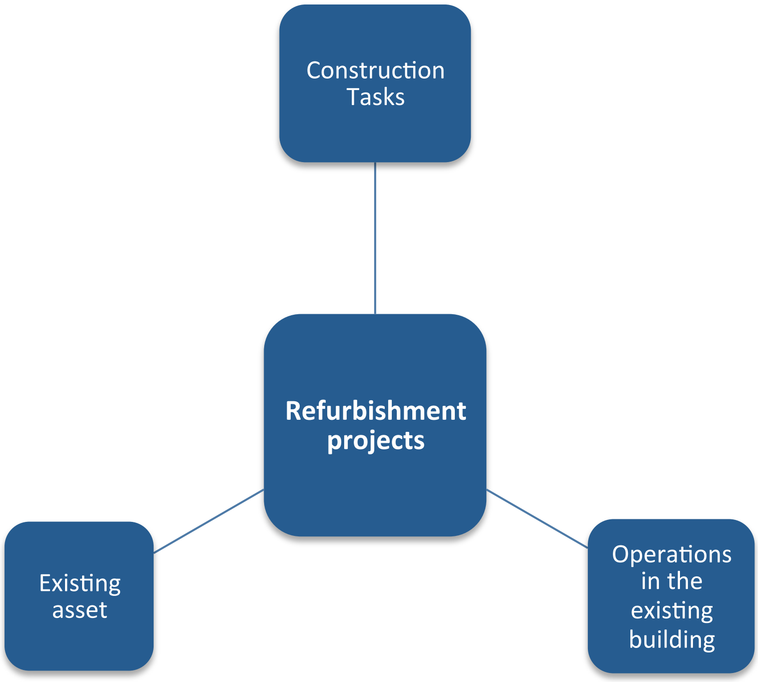

Figure 24 - The basic elements of a refurbishment project

Empirical evidence suggests that the three elements depicted in the figure above are interconnected (Figure 25). This means that if one wants to perform works on site effectively, then it is primary to have a deep understanding of the existing asset as well as it is fundamental to consider the operations in the building. In other words, the lack of integration between those three elements can be detrimental to project performance.

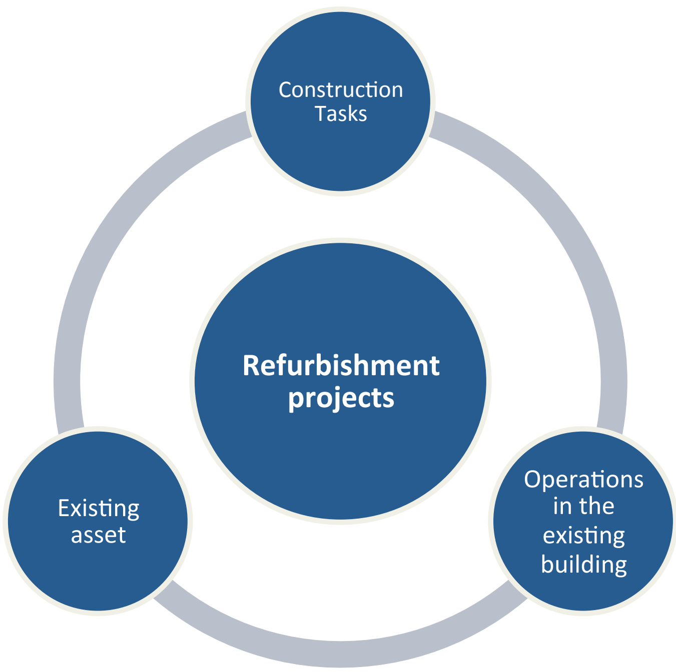

Figure 25 – The conceptual model of refurbishment projects

The conceptual model aims at increasing awareness of project participants regarding the nature of the project. In addition, it is contended that it facilitates the understanding of the subject for both academics and practitioners and serves as a reference basis for improvements.

4.3.1.2 Framework for characterisation of refurbishment projects

The proposed framework (Figure 26) is based on the notion that a better understanding of the project environment enables discussions and actions that support the management of complexity. This insight was gained during the literature review on complex and uncertain projects. Yet, the artefact aligns with the concepts of common ground and shared understanding[21]. The former consists of common values, mutually known facts, and commonly held presumptions that serve as the starting point for any conversation or interaction between two or more people (Koskela, 2015). The latter refers to "the ability of multiple agents to coordinate their behaviours with respect to each other in order to support the realization of common goals or objectives" (Smart et al., 2009, p. 3). It is argued that the framework plays the role of providing common ground, therefore facilitating a shared understanding between project participants. This idea is gaining traction in the construction field as it has been seen as a precondition for enabling an effective communication and collaboration among stakeholders, which is essential for practical implementation of modern management practices (Koskela et al., 2016; Gomes et al., 2017).

Project Characteristics	Industry Sector
	Project
Design intent	
Scope of works	
Typical problems	
Sequence of works on site	
Organisational structure	
Building information	
Building occupation	

Figure 26 - Framework for characterisation of refurbishment projects

The dimensions addressed in the framework are concerned to project's internal and external settings, and also project organisation. The design intent refers to the overall target of the project (e.g. achieve 40% reduction in energy costs through retrofitting the building), which is normally set by the client. The scope of works is a description of the works required for achieving the design intent. Typical problems are problems or difficulties expected for a

[21] According to Koskela et al. (2016), there are many other terms and concepts that refer to preconditions for communication and collaboration in construction projects such as boundary objects, mediating artefacts, and standardised methods. For an initial synthesis on this set of concepts, please refer to Gomes et al. (2017).

given project (e.g. asbestos likely to be found in the existing building). The sequence of works on site refers to the order in which tasks are expected to be performed in a project. The way in which a project is structured in terms of the relationships among project participants is set through the organisational structure. Building information addresses the data available on the existing building (e.g. surveys, as-built drawings), and building occupation reports the situation with regards to users of the building (e.g. house will be void during refurbishment).

4.3.1.3 Candidate solutions for production management in refurbishment projects

The candidate solutions presented in this section comprise guidelines, principles of production management, and lean solutions. Guidelines refer to recommendations for better project management found in the literature on refurbishment projects and best practices, extracted from the two empirical studies. Principles of production management are derived from the TFV theory of production (Koskela, 2000), and lean solutions refer to managerial tools and techniques in line with the lean theory.

Guidelines from the literature:

- Foster collaboration, engagement, and early involvement;
- Safeguard users and existing operations in the building;
- Reduce uncertainty;
- Use appropriate contract strategies, procurement routes, and management systems;
- Provide contingencies;
- Work with skilled people in refurbishment projects.

Best practices from empirical study 1:

- Structured and collaborative preplanning process;
- Effective and constant communication with users of the building;
- Maintenance of essential services in the existing building;
- Daily site visits;
- Long-term relationship with people skilled in refurbishment projects;
- Use of visual aids to improve communication and decision making;
- Standardisation of materials' specification.

Best practices from empirical study 2:

- Standardisation of design features;
- Integration of internal clients during the design development;
- Early identification of project constraints;
- Collaborative site pre-inspections;
- Visual controls;

- Prototyping;
- Daily site visits.

Flow concept-related principles (Koskela, 2000):

- Reduce the share of non-value adding activities (waste);
- Compress lead time;
- Reduce variability;
- Simplify (by minimising the number of steps, parts, and linkages);
- Increase transparency;
- Increase flexibility.

Lean solutions:

- Production System Design;
- Last Planner System;
- Line of Balance;
- Visual Management;
- Cellular Manufacturing;
- Multiskilling;
- Prefabrication/Standardisation;
- Benchmarking.

It is argued that better project results can be achieved by implementing the candidate solutions mentioned above.

4.3.2 First version of the method

The method for construction management proposed here aims at improving production performance of refurbishment projects through the indication of appropriate approaches of production control. It consists of a combination of artefacts presented in the previous sections and it is organised in a sequence of four steps as presented in Figure 27.

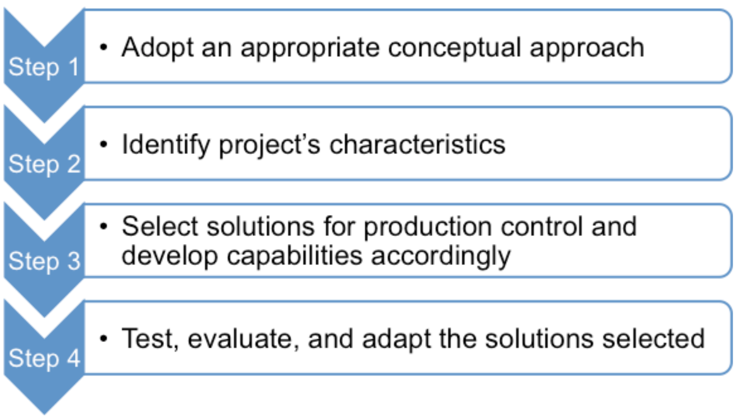

Figure 27 - Initial version of the method for construction management in refurbishment projects

The need for adopting an appropriate conceptual approach to support effective production management (Step 1) was identified initially during the literature review on construction management in refurbishment projects (section 3.1.1). Based on previous research, the author recognised that refurbishments present typical features that should be considered if one wants to improve the management of construction in this particular setting. This insight was confirmed later when several problems both in design and construction were spotted in one of the empirical studies (section 4.2.2.2) as a result of the lack of integration between the information related to the existing asset and the management of works on site. The importance of safeguarding users and operations in the existing building for ensuring a continuous workflow on site was also noted in the empirical studies, thus confirming the influence of such aspect on the performance of production.

The notion that a better understanding of the project environment allows discussions and actions that support the management of complexity is promoted in the literature on project complexity (section 3.2.1). The identification of project characteristics (Step 2) follows this reasoning. It is deemed as an essential step for selecting a suitable management approach.

The third step of the method addresses one of the key problems identified in the literature review on refurbishment projects (section 3.1.1.2) and confirmed during the development of the empirical studies, namely, the use of managerial methods not capable to cope with the complexity and uncertainty inherent to refurbishment projects. In order to tackle this problem, the author suggested a number of candidate solutions for production management (section 4.3.1.3). They refer to guidelines identified in the literature (section 3.1.2.1.3), best practices extracted from the empirical studies (sections 4.2.2.1.4 and 4.2.2.2.4), and managerial tools and techniques in line with the lean theory as presented in section 3.2.2.6.

The idea of testing, evaluating, and adapting the managerial solutions as indicated in the fourth step of the method emerged from previous studies that applied lean tools and techniques to refurbishments (section 3.2.2.5). This perception was corroborated in the third empirical study conducted as part of this research (section 5.2.3.1) when the author had to make some adaptations to the Last Planner System to suit the retrofit context.

In terms of the intended users of the method, it is argued that it is targeted to contractors and client organisations. This is because these are the companies that normally lead the development of refurbishment projects by interfacing with all stakeholders involved in the project. It is worth mentioning that the method is designed to be applied collaboratively. This means that project participants are meant to be involved during the implementation process. However, the appointment of a person to lead this process, for instance, a project manager or consultant is recommended. Next, further details are presented on each step of the method.

4.3.2.1 Step 1 – Adopt an appropriate conceptual approach

It is clear that the uncertainties related to the existing asset as well as the operations in the existing building influence the management of construction in refurbishment projects. Therefore, in order to improve production performance, the acknowledgment of the basic nature of refurbishments is primary. To this end, the adoption of the conceptual model of refurbishment projects proposed earlier in this thesis (Figure 25) is recommended. It is argued that approaching refurbishment projects from those three perspectives will support an effective construction management, hence leading to better project results. It is worth mentioning, however, that refurbishments might be also conceptualised in two parts depending on the project context, for instance, it is not in every project that operations in the existing building are on-going. Thus, a two-part conceptualisation can be also adopted.

4.3.2.2 Step 2 – Identify project's characteristics

Understanding the project environment is essential for the definition of the management system to be implemented in a project. Moreover, it is helpful in the management of complexity and uncertainty intrinsic to refurbishments. Therefore, the identification of project's characteristics is recommended. It is argued that such assessments can be done through the framework presented previously (Figure 26). Data should be collected and analysed in a collaborative fashion to ensure different perspectives are considered. It is fundamental that representatives of every organisation involved in the refurbishment are aware of the project situation in order to improve project performance.

4.3.2.3 Step 3 – Select solutions for production control and develop capabilities accordingly

Once the project is understood in terms of its basic nature and typical features then it is time for selecting the managerial solutions for production control and also ensuring people are trained accordingly for allowing an adequate implementation. The candidate solutions proposed in this thesis will serve as the starting point to the person who is going to lead this process (e.g. project manager or consultant). It is noteworthy that this person should have knowledge on lean concepts and principles, since this is the management approach upon which the tools and techniques recommended in this thesis are based.

It is worth mentioning that, at this point in the research, it was still not clear the criteria on how to select/combine the right configuration of candidate solutions to be implemented in a given project. This is because the process of selecting solutions for production control was not fully developed at this point. This issue was clarified during the implementation of the method in a real project, which is presented in the next chapter of the thesis.

4.3.2.4 Step 4 – Test, evaluate, and adapt the solutions selected

A basic principle of the method is that no solution should be taken for granted as effective or adequate for managing production in refurbishment projects. Therefore, it is argued that every managerial solution selected to be implemented in a project needs to be empirically tested and evaluated in terms of its usefulness. Also, adaptations might be necessary to allow the implementation of tools in the refurbishment context. It is contended that this practical evaluation will be instrumental for identifying implementation issues. It is worth mentioning that this recommendation addresses an issue identified during the literature review (section 3.1.2.3), namely, the lack of evidence on the practical implementation of guidelines for improving the management of refurbishment projects.

In the next chapter, the practical implementation of the method for construction management in refurbishment proposed above is described.

Chapter 5 Artefact implementation and refinement

The implementation and refinement of the method for construction management in refurbishment projects proposed in this thesis is presented in this chapter (Figure 28). An empirical study on the retrofit of a set of houses was carried out with the purpose of evaluating the utility of the method in a real project. This practical test was instrumental for improving the artefact as major alterations were made on its original design. In the next sections, further details about the artefact implementation and refinement are provided.

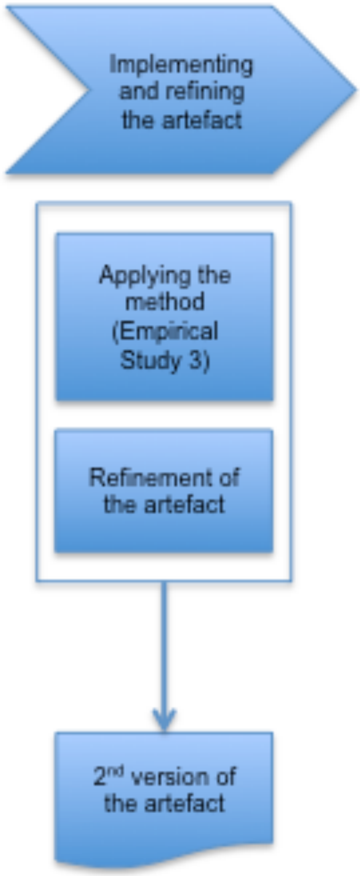

Figure 28 - Research process adopted for testing and refining the method

5.1 Empirical study 3

The first version of the method proposed in the thesis was tested through an investigation carried out in Northern Ireland between January and December 2015. Since it is the third study conducted throughout the research it is named as empirical study 3. It concerns the retrofit of eight nearly similar homes undertaken in five phases (Figure 29). Such a project was considered ideal for the research purposes, as the learning regarding the refurbishment work in one phase could straightaway be implemented in the next one.

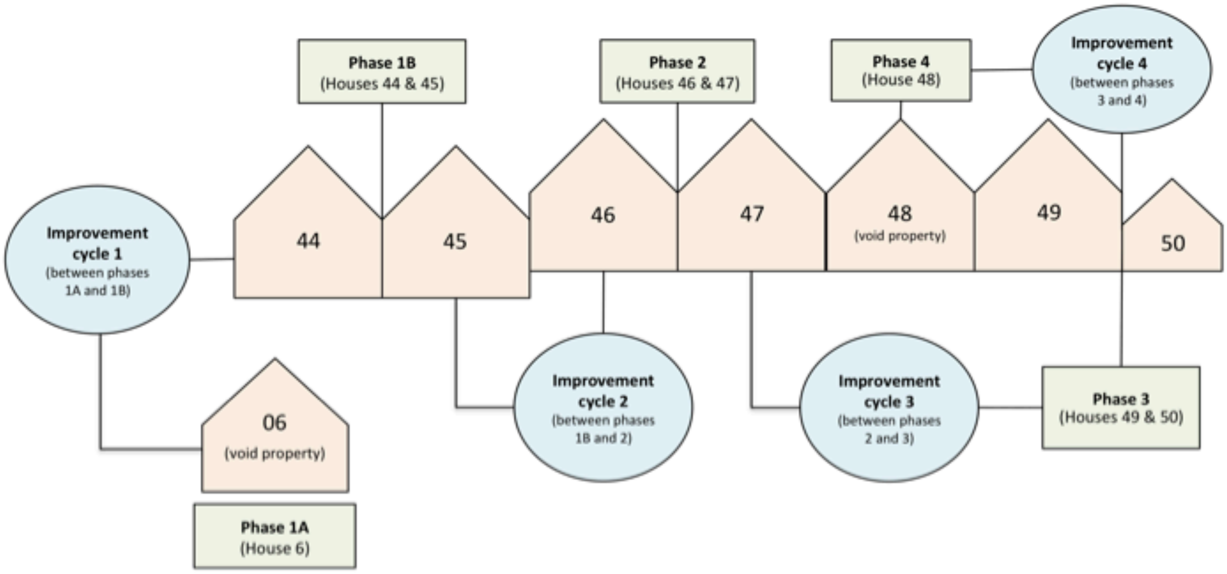

Figure 29 - Project phases and improvement cycles planned for the study

The author collaborated closely with the team involved in the project in order to test and refine the method and its components. Several sources of data collection were employed during the study such as semi-structured interviews (Table 21), participant observation in planning meetings and training sessions, observation of works on site (Table 22), and documental analysis (Table 23).

Table 21 - List of interviews carried out in empirical study 3

Interview	Interviewee's position	Organisation	Job functions
1	Project Leader	Research organisation	Responsible for managing the S-impler Project. Yet, provides technical support for the delivery of work packages and is also responsible for the dissemination of project's results
2	Project Manager	Contractor	Overall responsibility for the delivery of retrofits, performs tasks such as procurement, production planning and control, logistics, and management of subcontractors
3	Site Manager	Subcontractor	Responsible for managing workforce, programme, health and safety, and quality of works on site
4	Construction Monitor	Research organisation	Assist the research project leader by monitoring the execution of the retrofits in the field
5	Architect	Architectural practice	Responsible for the design of all systems, coordinate information, and liaises with the research organisation on energy modelling
6	Client	Housing Association	Overseeing effective delivery of retrofits, provides information regarding housing association's standards
7	CEO	Software company	Provides a tool for building surveying and managing the construction process by monitoring the progress on site
8	Senior Housing Energy Consultant	Research organisation	Project technical lead on specification, detailing and implementation
9	Consultant	Consultancy on Process Improvement	Performance improvement throughout the supply chain, including behavioural matters and contracts

Table 22 - Observations carried out throughout the study

Observation	What was observed	Place where the observation was conducted
1	Production planning and control meetings	Site office
2	Improvement meeting	Site office
3	Retrofit works	On site (retrofit of three houses)

Table 23 - List of documents assessed during the study

Document	Title	User	Information displayed in the document
1	Project Overview	Research team and Delivery team	Gantt chart for all research phases
2	Master Plan	Research team and Delivery team	Design, Construction, and Improvement Programme for phases 1A and 1B
3	Production plan (medium term)	Delivery team	List of activities for a given project phase along with list of constraints for releasing works on site
4	Production plan (short term)	Delivery team	List of activities planned for the week / day
5	Design drawings	Delivery team	Drawings containing the design specifications
6	Research proposal	Research team	Summary of the content and objectives of the wider research project, including scope of works, business proposition, and details (e.g. programme, risks, etc.)
7	Messages from Basecamp	Research team and Delivery team	It refers to conversations between project participants on issues concerning the retrofit delivery. Information was extracted from Basecamp, i.e. a collaborative web-based platform utilised for project management

This study was part of a wider research project focused on the retrofit of solid wall homes with the purpose to improve energy efficiency, reduce cost, and minimize user's disruption through the construction process. Next, further details about this project are provided.

5.1.1 The S-impler Project

This empirical study 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 at developing 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 (contractor), a subcontractor, a consultant on continuous improvement, an architectural practice, a company specialised on energy management solutions, a software company, and material suppliers. 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;
- Installation of heating controls and sensors;
- Replacing the existing oil boiler with natural gas boiler heating system;
- Replacing the ventilation system with a more efficient one.

The external wall insulation (EWI) adopted in this project refers to a system (Figure 30) that involves a layer of insulation material (i.e. boards made of expanded polystyrene) fixed to the wall, which is covered with a reinforcing material (i.e. fibreglass mesh) and rendering.

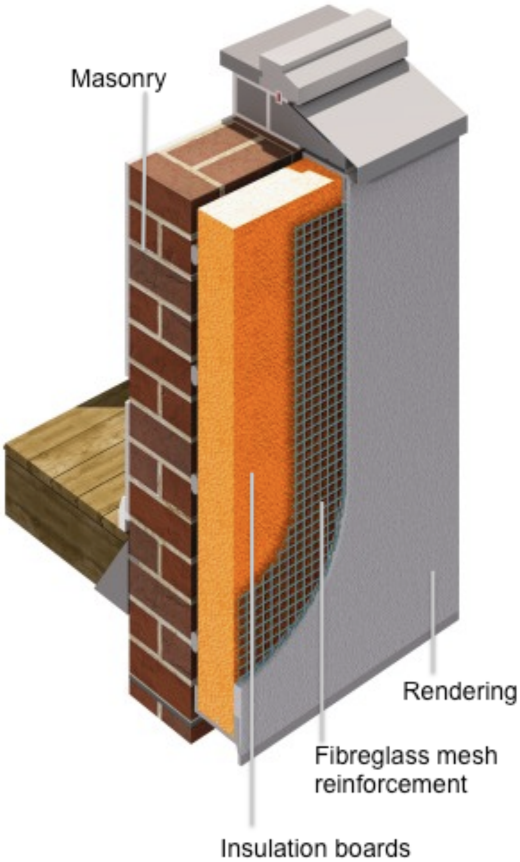

Figure 30 - Components of the external wall insulation system (Source: Jablite[22])

According to the supplier of insulation boards, dynamic[23] insulation provides both insulation and heat recovery and also improves ventilation within the building (Jablite, 2017). This

[22] Established in 1973, Jablite is the UK's largest producer of expanded polystyrene (EPS) insulation products and civil engineering solutions. Retrieved from http://www.jablite.co.uk/about-pages/about-us/

[23] This is known as dynamic insulation as the U-value is no longer constant for a given wall but varies with the speed of the air flowing through the insulation. The U-value refers to rate of transfer of heat through a structure (which can be a single material or composite), divided by the difference in temperature across the structure. The better insulated a structure is, the lower the U-value will be (National Building Specification [NBS], 2015).

system was selected for this project because it has the advantage of being installed without having to relocate the occupants of the property.

Several factors contributed to add complexity to this project: the high number of organisations involved, the fact that works were carried out in occupied homes (except from the retrofit conducted in phase 1A), and the adoption of a distinct method of construction (i.e. external wall insulation). Besides, the scope of works was considerably bigger when compared to traditional refurbishment schemes conducted by the housing association. According to project manager, typical retrofits involved solely internal insulation, but this one comprises heating controls, ventilation system, insulation, windows and doors, sensors, etc., so it was more in-depth than the other schemes he had been part of in the past.

Finally, it is noteworthy that the application of lean concepts is part of the elements investigated in the S-IMPLER Project. Thus, this project offers an interesting opportunity to evaluate the artefacts proposed in the thesis. In the following section, the research strategy employed for implementing the proposed method is presented.

5.1.2 Research strategy for testing and refining the method for construction management in refurbishment projects

The author was the person who led the implementation of the method in the retrofit. As mentioned earlier, the plan was to implement the method throughout the five phases of the project to allow learning and improvements between phases. However, due to the research limited timeframe and unforeseen circumstances faced during the development of this empirical study, the researcher could not finalise the study as planned. As a result, the test of the artefact was conducted through two phases as shown in Table 24.

The first stage of the study (phase 1A) was exploratory, i.e. the researcher made no intervention in the production management system in place. The main goal was to understand the methods and practices utilised by the contractor for managing production as well as identifying project’s characteristics. The data collection was based on artefacts devised earlier in this thesis, i.e. the conceptual model of refurbishments (Step 1) and the framework for characterisation of projects (Step 2). This phase was helpful for identifying problems in the management of works on site and their root causes. In order to achieve the goals set for this initial stage, several research methods were used, such as semi-structured interviews with project participants, direct observation of works on site, non-participant observations in planning meetings, and documental analysis.

The second stage of the empirical study was carried out through a workshop set up between phases 1A and 1B. This meeting was originally designed within the S-IMPLER’s framework as an improvement cycle, with the purpose of discussing with the project team the problems faced throughout the retrofit in phase 1A, as well as improvements for the next phase (1B). Thus, the researcher took this moment to validate the data collected in phase

1A (Step 2), to discuss with project participants the worth of managerial solutions to be tested in the subsequent phase of the project, for improving its performance, (Step 3), and to introduce the method devised in the thesis in order to get feedback on the utility of the artefact.

Table 24 - Research process

	Implementation			**Refinement**
	Phase 1A	Gate for phase 1B	Phase 1B	
Objectives	(a) Understanding of current production planning system and project's features (b) Problem identification along with root cause analysis	(a) Validation of research findings from phase 1A (b) Proposition of countermeasures to address the root causes of problems spotted in phase 1A (c) Presentation of the method devised in the thesis (d) Feedback on the utility of the artefact	(a) Implementation of managerial solutions selected previously (b) Evaluation of the efficacy of solutions tested	(a) Evaluation of the utility of the method (b) Refinement of the initial version of the method
Steps of the method proposed in the thesis	Data collection based on the conceptual model (Step 1) and framework (Step 2) devised in the thesis	Step 2 (validation of data collected in phase 1A) Step 3 (selection of managerial solutions to be implemented in phase 1B)	Step 4 (test, evaluation, and adaptation of managerial solutions selected previously)	
Research methods	Semi-structured interviews, non-participant observation in planning meetings, direct observations of works on site, documental analysis	Workshop with project participants (Improvement cycle)	Participant observations in planning meetings, direct observations of works on site, documental analysis	Learning cycle (reflection on the implementation of the method)

The implementation of the managerial solutions (Step 4) selected during the workshop was conducted in phase 1B. This practical test allowed the evaluation of the efficacy of the solutions chosen previously for managing the retrofit works. The researcher took a proactive approach in this phase by facilitating training sessions and production planning and control meetings. Data was collected through participation in production planning meetings, direct observations of works on site, and documental analysis.

Finally, a learning cycle was planned after the end of phase 1B. It aimed at reflecting upon the implementation of the method in order to evaluate its practical utility. This assessment allowed the researcher to promote refinements on the original version of the artefact.

5.2 *Implementing the artefact*

5.2.1 Phase 1A – Retrofit of house No. 6

The first phase involved the retrofit of one house (Figure 31). The team assembled for the delivery phase was led by a project manager who was responsible for managing a group of materials suppliers, an architect responsible for the retrofit design, and a subcontractor assigned for carrying out the works on site, named as "the delivery team".

Figure 31 – Retrofit of house No. 6

As mentioned earlier, the author used the conceptual model of refurbishments (Step 1) and the framework for project's characterisation (Step 2) devised in the thesis as supporting tools for collecting data. According to the former, in order to be effective the production management in refurbishments have to be approached from three perspectives, i.e. the existing asset, the construction tasks, and the operations in the existing building. Thus, the researcher investigated how the delivery team was addressing those three parts.

Regarding the existing asset, no as-built drawings were available to guide the designer on the design development. Due to this, two surveys were conducted for gathering information on the condition of the house. First, a representative of the software company used a tool for building surveying to carry out a very detailed measured survey, which involved a 3D model to allow visual representation and coordination of design and also an Excel file containing data on the building physical condition. This information was handed over to the architect responsible for the retrofit design who conducted an additional survey to fill the gaps left in the first investigation. It was a slightly intrusive survey (e.g. he took floor boards out) that allowed him to understand every building component in order to know how the house was built, the alterations that may have been applied in the building fabric over its lifecycle, and the potential issues it may have got (e.g. asbestos, air leaks). The architect argued that this investigation was needed to better understand the characteristics of the building. It is noteworthy, however, that no representative of the delivery team apart from the architect himself participated in the building surveying process.

In respect of the operations in the existing building, no measures were taken because the house was void during the retrofit work.

In terms of the management of construction tasks, the delivery team utilised two processes, namely, preplanning and production planning and control. In order to get ready for the retrofit, the delivery team set up a preplanning meeting four weeks prior works were due to start on site. The main goals of this gathering were to devise the construction programme and phase sequencing as well as checking the prerequisites for the retrofit such as design information, material and labour supply. Such tasks were facilitated by the consultant and performed by the delivery team in a collaborative fashion through the use of post-it 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 construction phase was four weeks.

Throughout the construction phase, the production planning and control process was carried out on 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. Tasks were pushed on site without proper consideration of production system status. As a result, several problems emerged such as disruptions in the workflow (main problem), downtime, a high level of work in progress, rework, and ultimately long lead time. The project manager considered as root causes of those problems, the lack of materials (e.g. windows and insulation components), lack of information regarding the retrofit design (e.g. detailed drawings), and budget (e.g. costs were not known before work was undertaken). It is noteworthy that no formal document was used to register the difficulties faced on site, so these could not be addressed in a consistent way. The actual lead time for retrofitting the house was 11 weeks.

In terms of the general features of the project, the researcher based his data collection on the dimensions of the framework for characterisation of refurbishment projects (Step 2). The results are presented as follows:

Design intent – the retrofit aimed at achieving 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.

Scope of work – the following workpackages were created for delivering the retrofit: enabling works, MEP services, internal works, external works, windows and doors, insulation, rendering, and cleaning. Details on each workpackage are presented in Table 25.

Table 25 - Workpackages - initial version

Item	Workpackage	Tasks
1	Enabling works	Containers, Scaffolding, Skips; Inspections and minor works (drains, boiler, relocation of gas pipes, heating system, boiler access).
2	MEP services	Fit heating controls and sensors; Fit new ventilation system; Fit hot water cylinder.
3	Internal works	Loft insulation; Slab entrance hall; Rear lobby (remove partition wall, remove door, form timber floor, form frame to doors and windows, plasterboard to new areas).
4	External works	Excavate around below damp-proof course; Concrete step to front door; Roof extension (rear), strip back three rows of roof tiles, replace soft and fascia; Backfill trench.
5	Windows and doors	Replace windows and doors.
6	Insulation	Fit dynamic external wall insulation (includes extension rear); Fit solid insulation to corner.
7	Rendering	External wall render;
8	Cleaning	Tidy up the house.

Sequence of works on site – is represented in Figure 32.

Figure 32 - Sequence of works – Phase 1A – initial version

Typical problems – as mentioned earlier, the most common problems in phase 1A were disruptions in the workflow on site, downtime, high level of work in progress, rework, and long lead time. According to the project and site managers, these were caused by the lack of materials and information required for releasing works on site. Late asbestos assessment was also identified as a problematic issue that was caused by the lack of access to the loft of the house when the building was surveyed prior to starting the retrofit.

Organisational structure – the team responsible for the delivery of the retrofit comprised a project manager, three material suppliers, a subcontractor, and an architect. Yet, there was also a group called S-IMPLER team that was responsible for the development of the wider research project. The contractor, which worked as project manager in the delivery team, was the entity responsible to liaise with the S-IMPLER team regarding construction issues. The composition and relationship between both teams are illustrated in Figure 33.

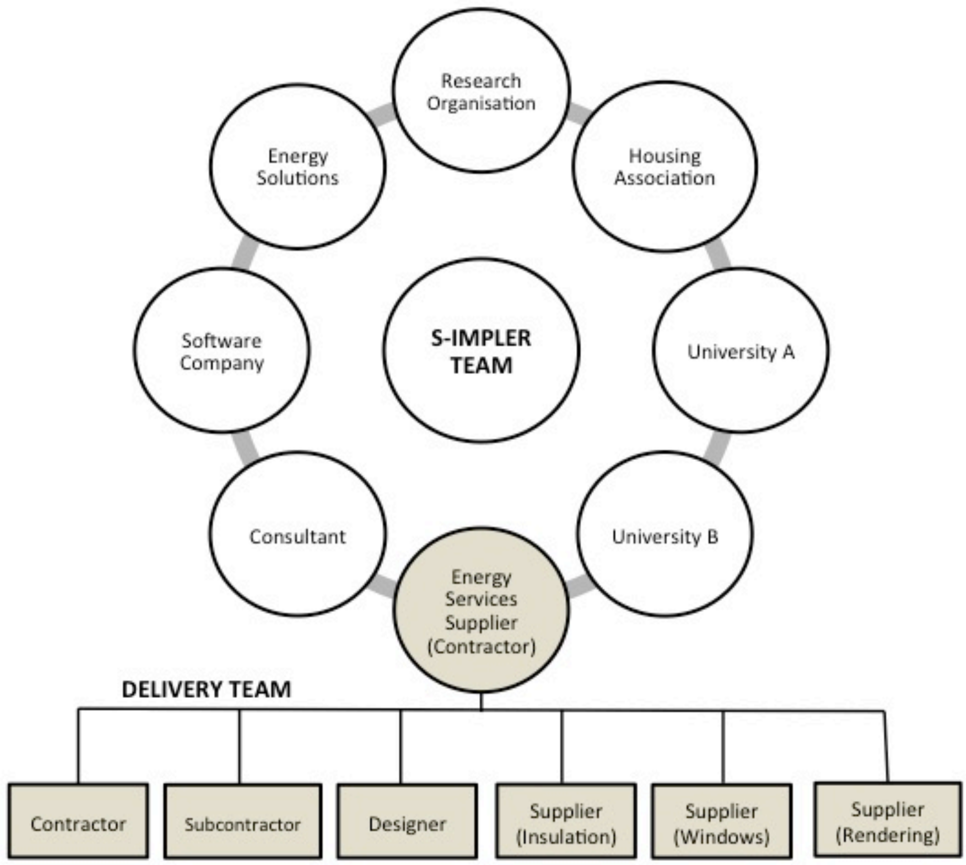

Figure 33 – Project Organisational Structure

Building information – no as-built available. Two detailed surveys were carried out to gather information on the condition of the house.

Building occupation – the house was void during the retrofit.

In order to validate the research findings from phase 1A and also promote improvements to phase 1B, a workshop was carried out two weeks after the end of the retrofit works. In the following section, further details are provided about that event.

5.2.2 Gate for phase 1B – Workshop on continuous improvement

The consultant and the researcher along with the project team carried out a seven hour workshop to validate the research findings from phase 1A and discuss on improvements to be implemented in phase 1B. In total, eleven people attended the event, i.e. the organisers aforementioned plus the project manager (contractor), site manager (subcontractor), construction monitor, three suppliers, architect, client, and senior housing energy consultant.

The workshop was structured in three parts. First, the information gathered in phase 1A was validated. Second, the managerial solutions suggested for improving project performance in phase 1B were discussed with the project team. Third, the method devised in the thesis was introduced to the workshop's attendees. Results of the workshop are presented in the following sections.

5.2.2.1 Validation of data collected in phase 1A

The framework for project's characterisation devised in the thesis was used as a supporting tool for enabling discussions during the workshop. The attendees validated the information concerning each dimension set in the framework. The results are presented as follows:

Design intent – there was an agreement on the overall goals set for the project, but the target regarding the retrofit lead time was not clear. As mentioned earlier, the aim was to execute the retrofit 10% faster than conventional installations; however there was not a consensus within the team on how long a typical retrofit would last if considered the same scope of works. Thus, the project participants decided to keep four weeks as a target for the construction works in phase 1B.

Scope of works – according to the project manager, information gathered previously was incomplete because more tasks were added to the original scope of works during phase 1A. Also, the attendees argued that those works could be structured in a better way. Thus, a revised version of workpackages for delivering the retrofit was generated (Table 26).

Sequence of works on site – the initial sequence was reorganised based on the revised work structure[24]. The updated sequence of works is presented in Figure 34:

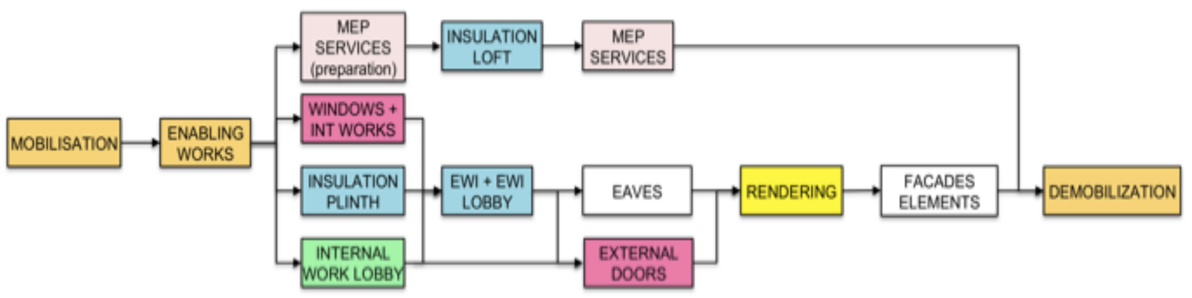

Figure 34 - Sequence of works - phase 1A - revised version

Typical problems – the problems identified in phase 1A were organised and presented to project participants according to the conceptual model of refurbishment projects devised in the thesis (Step 1). The attendees agreed with the problems spotted by the researcher and added an additional issue, i.e. inefficient coordination and collaboration among the team. However, there was divergence regarding the origin of those problems. Thus, the attendees conducted a root cause analysis. The results are presented in Table 27.

[24] In the revised version of the sequence of works, the external wall insulation (EWI) is divided into two parts, namely, the EWI and EWI lobby. The former refers to the insulation installed in the entire house whereas the latter concerns to a particular area built at the rear of the building, which was referred as 'lobby' by the delivery team.

Table 26 - Workpackages - revised version

Item	Workpackage	Tasks
1	Mobilisation	Erection of scaffolding, skips on site, organise site containers.
2	Enabling works	Pre-inspections (e.g. boiler flue/condensate, boiler access, finishing around windows, drains, pipes, heating system); Remove façade elements (satellite dish, lighting, rainwater downpipes); Relocation of pipes (rainwater) and drains; Cutting external sills.
3	MEP Services (preparation)	Preparation works (e.g. holes for inlets and outlets, inlets trough external wall insulation, ducting, heating system flue, outlet into hall, hole for bathroom extractor fan)
4	MEP Services	Fit heating controls and sensors; Fit new ventilation system, hot water cylinder, extractor fan (bathroom); Commissioning of system and controls.
5	Windows + Internal Works	Windows (remove existing frames, windows, sills; insulate new frame; fit new sills, frames, windows, sill end caps; seal windows); Internal works (remove curtain rails; bricking wall under windows; plaster around windows; plaster internal walls).
6	External doors	Remove existing external walls; Plasterboard front door entrance; Concrete step front and rear doors; Fit new doors.
7	Internal works (Lobby)	Knock down partition wall and external wall; Build new external wall, new flat roof (wood, plasterboard, insulation); Fit new door; Latex to front door and rear lobby plus tile; Skirting to front and rear lobby; Plaster to internal walls of lobby.
8	Insulation plinth	Clear and insulate plinth; Below damp-proof course external insulation.
9	Insulation loft	Spray foam perimeter; Laying rolls; Install loft hatch draught proofing.
10	External Wall Insulation (EWI)	EWI base rail (starter track); Dynamic and solid EWI boards; Insulation around eaves, windows, doors, and lobby; Fit corner mesh and seal gaps on insulation.
11	Eaves	Remove existing fascia, soffit, and guttering; Fit gutter rails; install gutter, and fit fascia and soffit.
12	Rendering	External wall render according to the following steps: 1-base coat; 2-bed glass fibre mesh; 3-second coat; 4-primer; 5-finishing coat.
13	Façade elements	Replace satellite dish, lighting, and rainwater downpipes
14	Demobilisation	Scaffolding down, cleaning site.

Table 27 - Root cause analysis of problems faced in phase 1A

Refurbishment	Problem	Root causes
Existing asset	Late asbestos assessment	This problem happened because the surveyor could not access the loft when the building surveying was conducted prior the start of the retrofit. He informed the housing association about this issue but could not get back on time for checking the loft. It was concluded then that a slow communication between project parties caused the problem. However, it was argued during the workshop that this problem was not an important issue since no extra time or disruption were caused as a result.
Construction Tasks	Inefficient coordination and collaboration among the team	The lack of a clear communication structure and information flow was the root cause of those problems. Aspects regarding the management of the project (e.g. roles and responsibilities) were not clear at the outset. For example, the project manager was not sure about his role in the retrofit when the author interviewed him in the beginning of the project.
	Disruptions, downtime, and high level of work in progress	Initially, the lack of materials and information were deemed as causes of those problems. However, the delivery team found out later on that such problems were caused mostly due to an inappropriate production planning and control system as tasks could not be pushed on site as planned if a prerequisite was missing. In other words, the planning approach utilised in phase 1A failed to shield production against uncertainties.
	Delays to start works on site due to delays in the delivery of materials	Wrong sized windows were delivered on site because there was an error of measurement before placing the material's order. The person who made the mistake said it happened because it was not clear how to do the measurements since the product applied in the retrofit was new to him.
	Rework (windows)	Similarly to the problem above, the lack of information on how to measure windows caused this problem.
	Long lead time (11 weeks)	This problem occurred as a result of the issues cited above. However, two aspects were considered as root causes, namely, poor communication among the team due to lack of a clear definition of roles and responsibilities and inadequate production planning approach as tasks were pushed on site without proper consideration of production system status.
Operations in the existing building	No problem was identified on this regard as the house was void during the retrofit	N/A

Organisational structure – the configuration presented in Figure 33 was validated.

Building information – the client confirmed that the housing association had no as-built drawings available and the architect validated the details about the two surveys carried out for gathering information on the condition of the house.

Building occupation – the house was void during the retrofit.

The next step after the data validation was the discussion on improvements for phase 1B. In the following section, further details about the second part of the workshop are provided.

5.2.2.2 Improvement suggestions for phase 1B

The second part of the workshop aimed at proposing countermeasures to address the root causes of the problems identified in phase 1A. To this end, a two-pronged approach was adopted. Firstly, an opportunity was given to project participants to voice their opinion in terms of improvements that could be made in phase 1B based on the root cause analysis carried out previously. The attendees decided that no works on site should get started until all uncertainties were resolved (e.g. design issues, material specifications, cost approval). This decision was made in order to prevent disruptions in the workflow and downtime, thus 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 consultant in order to streamline the communication and foster collaboration amongst the team. Besides, the organisational structure of the project (Figure 33) was clarified throughout the workshop.

Secondly, countermeasures based on the candidate solutions identified earlier in this research were also suggested as potential improvements. The author met the consultant before the workshop took place and introduced to him the candidate's solutions in order to assess whether they could be useful for addressing the problems identified in phase 1A. A number of managerial practices and methods were selected during this meeting. These are presented as follows:

- Foster collaboration, engagement, and early involvement;
- Reduce uncertainty;
- Use of visual aids to improve communication and decision-making;
- Early identification of project constraints;
- Visual controls;
- Compress lead time;
- Reduce variability;
- Last Planner System;
- Visual Management;
- Standardisation.

The consultant appreciated the suggestions presented by the researcher, but he warned that there could be too much information to be introduced all at once and therefore suggested to narrow down to a few recommendations. The author proposed the implementation of the Last Planner System and argued that it could be a good starting point in terms of improvements because that tool has embedded on its design several practices mentioned above such as uncertainty and variability reduction, collaboration, engagement, and early identification of project constraints. The use of visual aids to improve coordination and decision-making is also considered during LPS meetings. He contended that the LPS could be useful to reduce disruption in the workflow on site, hence enabling the compression of project's lead time. Thus, the LPS was presented to the attendees during the workshop and included as an improvement for the next phase of the project. The problems faced in phase 1A are summarised in Table 28 along with their root causes and the countermeasures suggested for improving project performance in phase 1B.

Table 28 – Problems, root causes (phase 1A) and candidate solutions (phase 1B)

Problems faced in phase 1A	Root causes of problems	Countermeasures
Inefficient coordination and collaboration among the team	Lack of a clear communication structure and information flow	A meeting was arranged with the team to streamline communication and collaboration; A web-based project management platform was set up for improving communication among the team; Project organisational structure was clarified during the workshop.
Disruptions in the workflow on site, downtime, and high level of work in progress	Inappropriate production planning and control system in place	Shield production against uncertainties; Implement Last Planner System.
Late material delivery and rework	Lack of information for helping with the window's measurements	Use of Visual Management to improve communication and support standard work. For instance, use of work standard procedures (laminated A3 on site to show how work should be done).
Long retrofit lead time	Poor communication/collaboration among the team and inadequate production planning approach	Improve clarity in terms of roles and responsibilities; Shield production against uncertainties; Implement Last Planner System.

Lastly, it is noteworthy that the countermeasures presented earlier focused on tackling the root causes of problems faced in phase 1A. However, there is an important feature of the retrofit in phase 1B that cannot be overlooked, namely, the fact that construction will be conducted in occupied buildings. Consequently, based on the candidate solutions identified throughout his research, the author suggested the following guidelines as a complement to the recommendations mentioned above.

- Safeguard users and existing operations in the building (e.g. train site personnel in order to avoid unnecessary issues with tenants, minimise disruptions via proper planning);
- Effective and continuous communication with tenants (i.e. keep tenants fully informed about the progress of works);
- Maintenance of essential services in the existing building (e.g. heating, water and electricity supply, etc.).

The workshop's attendees agreed with those recommendations and decided to take them into account in the next phase of the project. After the discussion on improvements, the participants set targets for phase 1B. These are presented as follows:

- Retrofit lead time – 4 weeks;

- No disruption due to delays of material deliveries and lack of information;
- No rework;
- No changes in the scope of works without cost information and formal approval.

In the following section, the subject addressed in the final part of the workshop is presented, namely, the method for construction management in refurbishment projects.

5.2.2.3 Feedback to the presented method for construction management in refurbishment projects

The last part of the workshop was dedicated to the introduction of the method to project participants. The presentation of the artefact was divided into three parts. First, details on how the method was developed were explained. This involved the presentation of findings from the literature and from the empirical studies carried out during the development of the research. Second, an overview of the artefact was provided based on Figure 35.

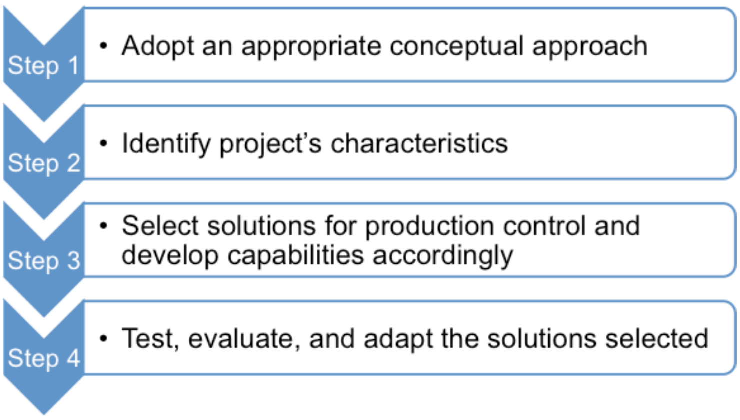

Figure 35 - First version of the method

The researcher explained each step of the method, the aim of the artefact, and the benefits expected from its implementation. These are listed as follows:

- Improved reliability in terms of cost and time;
- Compressed project schedule;
- Improved predictability of workflow on site with positive impact on safety;
- Reduced waste (e.g. disruptions on site, waiting time, etc.);
- Improved production control;
- Increased customer satisfaction due to improvements on plan's reliability.

Third, the candidate solutions for improving production management in refurbishment projects were also presented. They comprised guidelines from the literature, best practices extracted from empirical studies, principles of production management according to the TFV theory, and also managerial tools and techniques in line with the lean theory.

After the introduction of the artefact, the author seized the opportunity to get feedback from participants on the utility of the method. The attendees considered the artefact as a structured way to approach the management of refurbishment projects, but they were cautious on the benefits expected by its implementation. They said it would be prudent to wait until the retrofit in phase 1B was completed in order to take the project results into consideration in the assessment. The author then asked their opinion on the usefulness of each step of the method. The conceptual model of refurbishments (Step 1) was recognised by all attendees as an accurate representation of those projects. Yet, they liked the idea of using the three parts of a refurbishment (i.e. the existing asset, the construction tasks, and the operations in the existing building) as a structure for locating the problems faced during the retrofit (Table 27). On the framework for project's characterisation (Step 2), they said it was a practical way to make everyone involved in the retrofit aware of project's features. They said the discussions based on the dimensions set in the framework were helpful in the definition of countermeasures for problems faced in phase 1A. Besides, they suggested the inclusion of two new dimensions, namely, project driver and root causes. The former would aim at clarifying the main constraint or difficulty faced in the project (e.g. operations cannot be stopped during construction), while the latter would shed light on the reasons that led to a given problem. Regarding the third step of the method, the attendees proposed that the development of capabilities to enable the implementation of managerial solutions could be considered as a separate step. They argued that training sessions are distinct activities, which would not be conducted in the same day when the countermeasures were selected. No comment was made on the fourth step of the method.

5.2.3 Phase 1B – Retrofit of houses No. 44 and 45

The second phase of the project involved the retrofit of two houses, both occupied during the construction. The composition of the delivery team was exactly the same as in the phase 1A. Four weeks was the lead time planned for the retrofit of both houses.

As noted in Table 28, several countermeasures were suggested as candidate solutions for improving the performance of the retrofit in phase 1B. Some of them, namely, the meeting for streamlining communication and collaboration, the clarification with regards the project organisational structure, and the setup of a web-based project management platform were carried out prior the start of works on site. Therefore, the next section is focused on the implementation of Last Planner System (LPS) of production control. It is noteworthy that 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.

5.2.3.1 *Application of the Last Planner System for managing works on site*

In order to implement the LPS in such specific project context, some adaptations had to be made. These are summarised in Table 29.

Table 29 - Adaptations to the Last Planner System to suit the retrofit context

LPS Elements	Phase 1B
Long term (master plan)	Devised in a collaborative fashion by the delivery team through the use of post-it notes and a location-based chart
Phase Planning	
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 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 a short amount of time. Such a plan is referred as "master plan" and 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 Figure 36.

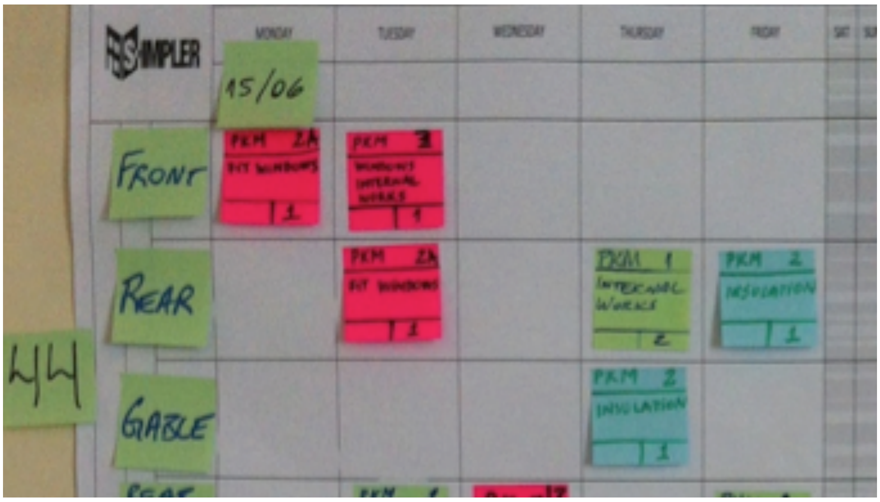

Figure 36 - Post-it notes fixed on a location-based chart at the site office (master plan)

The number 44 in Figure 36 represents the house number and the locations (e.g. front, rear) refer to the façades of the house. The selection of façades as programming batches is due to the main retrofit processes (e.g. windows and doors, external wall insulation, and rendering) being executed in those 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 look ahead planning was carried out before the start of the retrofit 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 conducted on a daily basis as well as the PPC measurements and root cause analysis. The actual lead time for retrofitting both houses was six weeks.

In terms of problems, there were still disruptions in the workflow due to the lack of materials. However, the root cause of those interruptions was linked to a failure in checking the quantity of material available for carrying out the insulation works. It is worth mentioning that those disruptions were considered as a minor problem and not a major issue as noted in phase 1A. Another problem faced during phase 1B was the lack of subcontractor's collaboration in the planning meetings, as the foreman showed resistance to formalising 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, the team agreed that models should be redeveloped with a lower level of detail. Also, 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.

5.2.3.2 Efficacy of the Last Planner System for managing works on site

The compression of lead time noted between phase 1A (eleven weeks) and phase 1B (six 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 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. Yet, this list can be seen as 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 29). 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 plans were put in place instead of weekly ones in order to enable the creation of basic stability and establishment of short learning cycles. Also, the use of visual aids 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 in phase 1B as it precluded the appropriate formalisation of daily production plans and, as a result, hindered the evaluation of daily production performance as planned. This highlights the need of gaining top management support prior the implementation of the 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. Yet, the 4D BIM models were 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.

5.3 Refining the artefact

In order to enable the refinement of the method and its components, a learning cycle was conducted after the end of phase 1B. It was the last stage of the empirical study designed for testing and refining the artefact. The researcher reflected upon the implementation of the artefact in order to evaluate its practical utility. Several insights were gained throughout the study. These, in turn, contributed to the refinement of the initial version of the method. Next, the results of this assessment are presented.

5.3.1 Utility of the method for construction management in refurbishment projects

In order to assess the usefulness of the artefact, it is necessary to be reminded of its purpose. As noted earlier, the method proposed in the thesis aims at improving production performance of refurbishment projects through the indication of appropriate approaches of production control. From this perspective, it is possible to conclude that the method has reached its objective given that a significant enhancement in the performance of the project was realised from phase 1A to phase 1B, namely, the retrofit lead time was compressed to six weeks. Additional benefits realised from improvements on production management include: reduced waste (e.g. decreased waiting time due to less disruptions in the workflow on site), smoother workflow on site if compared to the previous phase of the project, and improved customer satisfaction as the retrofit lead time was significantly reduced. It is argued that those advancements resulted mainly from the implementation of a method of production planning and control suitable for coping with the uncertainties intrinsic to refurbishment projects, i.e. Last Planner System. As noted in the previous section, principles associated to LPS contributed to reduce disruptions on site and compress the retrofit's lead time. The improvements on project coordination and communication are also noteworthy. Evidently, other countermeasures cited earlier such as the clarification of roles and responsibilities of each part involved in the project, the meetings for streamlining communication and foster collaboration among project participants, and the setting up of web-based project management played also an important role in phase 1B.

Finally, it is worth mentioning the importance of the conceptual model of refurbishments (Step 1) and the framework for characterising projects (Step 2). The former was helpful in making project participants conscious of the interconnection between refurbishment parts, namely, it is not only the administration of works on site that is important to be successful in a retrofit, but also the management of information regarding the existing asset and the operations in the existing building. The latter was useful to increase the awareness of the team on the complexity of the project. Besides, those artefacts were opportune for enabling discussions and actions on issues concerning the production management of the retrofit as demonstrated during the workshop carried out between phase 1A and phase 1B.

Despite the benefits mentioned above, improvements on the method and its components were promoted as a result of the implementation. These are presented in the next section.

5.3.2 Refinements of the initial version of the method

The practical test was fundamental to the refinement of the method devised in the thesis. The modifications made on the initial version of the artefact were based on the feedback from project participants during the workshop carried out between phase 1A and phase 1B and the perception of the researcher on the application of the method.

One of the alterations resultant from the implementation of the artefact refers to the increase on its number of steps, i.e. it went from four to eight. The third step of the original version of the method was split into two (Figure 37). This change was motivated by the feedback from project participants during the workshop on continuous improvement.

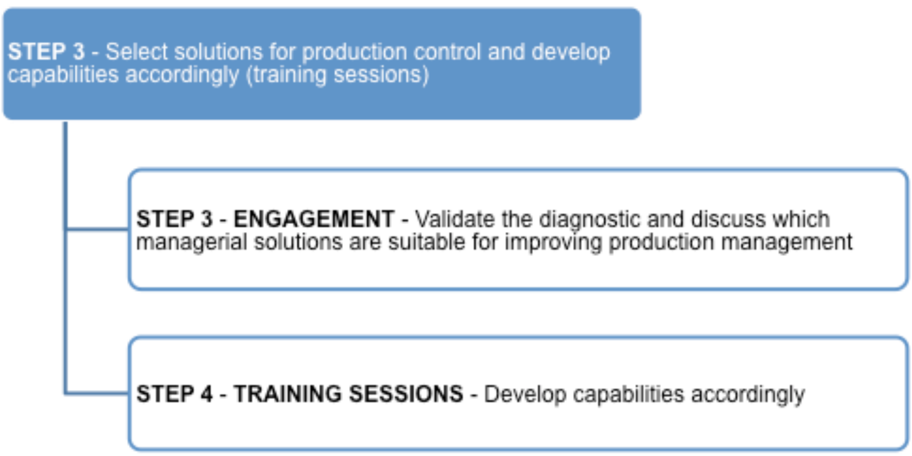

Figure 37 - Modification in the original design of the artefact

The fourth stage of the first version of the method was divided into three steps (Figure 38). Based on the application of the artefact, the author of the thesis decided that it would be better to approach the test, evaluation, and adaptation of managerial solutions separately rather than in a single step as they represent different activities with distinct emphases.

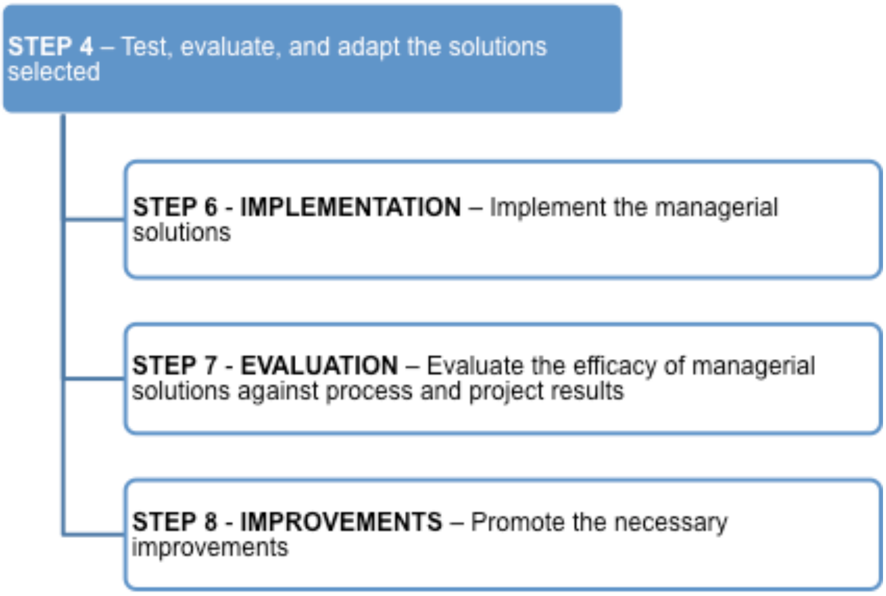

Figure 38 - Modification in the original design of the artefact

Besides, a new step called targets was created to designate the key performance indicators set for the project (Figure 39). This insight was gained during the workshop on continuous improvement when the attendees set the goals for phase 1B.

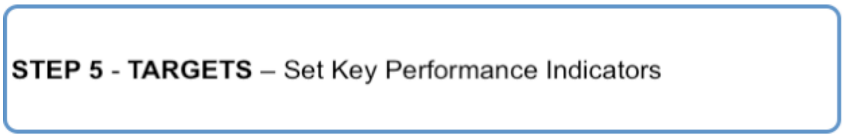

Figure 39 - New step created as a result of the implementation of the method

Components of the method such as the framework for characterisation of refurbishment projects and the candidate solutions for improving production management were also refined. As a result, a second version of the method was devised. These modifications are presented in the next sections. For the sake of consistency and in order to improve clarity, the author decided to address those improvements following the same structure used in the previous chapter, namely, the components of the method are presented first and then the method itself is described.

5.3.2.1 Conceptual model of refurbishment projects

The conceptual model of refurbishment projects is the only artefact that was not altered as a result of the practical implementation of the method. As mentioned earlier, the three parts shown in Figure 40 were considered as an accurate representation of refurbishments.

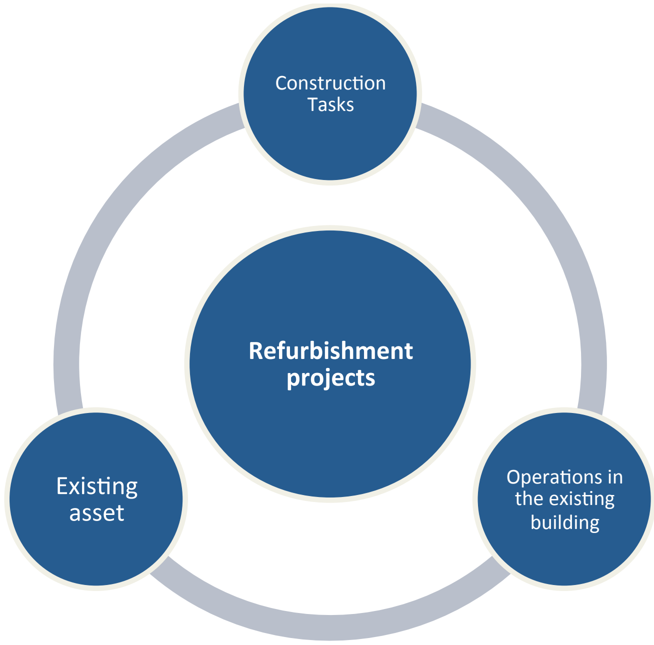

Figure 40 – The conceptual model of refurbishment projects

Besides, there was a consensus among project participants that in order to be effective the production management in refurbishments have to be approached from the three perspectives depicted above. Thus, the conceptual model was kept in its original form.

5.3.2.2 Framework for characterisation of refurbishment projects

Two new dimensions were added to the first version of the framework, namely, project driver and root causes (Figure 41). The former refers to the main constraint or difficulty faced in a given project (e.g. operations cannot be stopped during construction) whereas the latter is concerned to the basic reasons that led to a particular and typical problem.

Project Characteristics	Industry Sector
	Project
Design intent	
Project driver	
Scope of works	
Typical problems	
Root causes	
Sequence of works on site	
Organisational structure	
Building information	
Building occupation	

Figure 41 - Second version of the framework for characterisation of refurbishment projects

The other dimensions addressed in the framework were not removed or altered since the participants raised no objections to their use. On the contrary, they considered the artefact helpful for prompting discussions and actions on production management issues as well as establishing a common understanding regarding project's features.

5.3.2.3 Candidate solutions for production management in refurbishment projects

The criteria for selecting the candidate solutions for production management, which were not defined when the first version of the method was devised, became clear during the empirical study. A context-based approach was adopted with that purpose. It is argued that the understanding of project's characteristics and problems led to the adoption of managerial practices suitable for the refurbishment setting. Furthermore, the results obtained in phase 1B (e.g. compressed lead time, improved coordination) demonstrate that considering dimensions related to the project environment (Figure 41) for defining the production management system is indeed an effective approach. Therefore, a framework was devised connecting the features and problems commonly found in refurbishment projects to the managerial solutions identified during the research. These, in turn, were organised according to their nature, namely, conceptual and practical solutions. The former refers to flow concept-related principles derived from the TFV theory of production whereas the latter concerns to guidelines for better project management found in the literature, best practices extracted from empirical studies, and tools and techniques in line with the lean theory. The conceptual model of refurbishments devised in the thesis underpins the framework. The rationale behind the idea is synthesised in Figure 42.

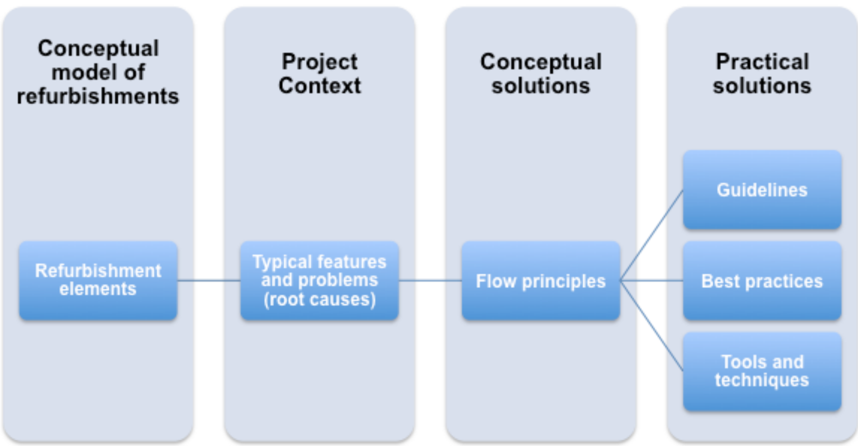

Figure 42 – Framework of managerial solutions for production management in refurbishment projects

In order to create the framework, several steps were accomplished by the author. First, the typical features of refurbishments and problems faced in these projects were summarised in line with the conceptual model proposed in the thesis (Table 30). This information was taken from the literature review and empirical studies.

Table 30 – Typical features and problems encountered in refurbishment projects

Refurbishment basic elements	Problem	Sources
Existing asset	As-built drawings are often unavailable and when they are available normally they are inaccurate	Sanvido and Riggs (1991), Quah (1992), CIRIA (1994) Mitropoulos and Howell (2002), empirical studies 1, 2, 3
	Lack of an appropriate understanding of the existing building	Empirical study 2; Baker et al., 2013
	Late discovery of pre-existing conditions (after design decisions had been made), therefore causing negative design iterations and rework	Mitropoulos and Howell (2002), empirical study 2
	Late involvement of stakeholders (i.e. no input of contractors and subcontractors in the building surveying), hence causing design-related rework	Mitropoulos and Howell (2002), empirical study 2
	Project scope can be unclear due to limited information about the existing asset	Sanvido and Riggs (1991), CIRIA (1994), Empirical studies 1, 2
	Hazardous material (e.g. asbestos) might be encountered in the existing building	Sanvido and Riggs (1991), CIRIA (1994), Egbu (1997), empirical study 3
Construction Tasks	Unknowns on site more prominent. Discovery of unforeseen conditions continue to happen during the construction phase	Quah (1992); CIRIA (1994); Krizek et al. (1996); Singh (2007); Howard et al. (2009), empirical studies 1, 2
	Inefficient communication, coordination, and collaboration among the project team	Krizek et al. (1996), Empirical studies 1, 3
	Short construction timeframes due to interference with building occupation and operation	Sanvido and Riggs (1991), Rahmat (1997), empirical studies 1, 2, 3
	High number of project's constraints such as space limitations (e.g. storage, new equipment, construction), restricted access, uncertainties on the condition of the existing asset, pollution control, etc.	Whiteman and Irwig (1988); CIRIA (1994), Rahmat (1997) Krizek et al. (1996), Mitropoulos and Howell (2002), Singh (2007)
	Wastes in production (e.g. waiting time, disruptions in the workflow, rework, downtime, high level of work in progress, unnecessary transport, etc.)	Henrich (2009), Empirical Study 1, 3
	Use of inappropriate managerial practices (e.g. highly detailed CPM plans, no contractor input on planning, thermostat model of control, etc.)	CIRIA, 1994; Egbu, 1996; Krizek et al., 1996; Egbu et al., 1998; McKim et al., 2000; Henrich, 2009; Empirical studies 1, 2, 3
	Poor performance in terms of cost, schedule, and quality in comparison with new building projects	McKim et al., 2000; Naaranoja and Uden, 2007; Ali et al., 2009; Empirical studies 2, 3
	Variability (unforeseen works and variation in the quantity of works, variation in the lead time)	Empirical studies 1, 2
	Difficulty to synchronise crews on site	Empirical study 1
	Delays in material delivery	Empirical studies 2, 3
Operations in the existing building	Operational constraints related to the existing facility. Need to interface with users of the building.	Sanvido and Riggs (1991), CIRIA (1994), Krizek et al. (1996), Howard et al. (2009)
	Dangerous work (e.g. project involving demolition). Safety issues due to the interface of construction works with existing operations in the building and users	CIRIA (1994), Egbu (1995); Anumba et al. (2004); Howard et al. (2009)
	Tenants (lack of compliance to agreed dates, late design change requests)	Empirical study 1
	Lack of integration between design, construction, and operations	Empirical study 2

Second, the researcher carried out a root cause analysis to identify the origin of problems (Table 31). This assessment was based on the knowledge he acquired through the research and it involved a reflection on findings from the literature and empirical studies. The use of inappropriate managerial practices (e.g. poor building surveying, use of highly detailed CPM plans, lack of involvement of production teams during planning and design processes, etc.) is the cause of most problems identified in refurbishment projects such as rework due to late discovery of pre-existing building conditions, ill-defined scope of works, wastes in production (e.g. waiting time, disruptions in the workflow on site, etc.), inefficient communication and collaboration, and ultimately poor performance in terms of cost, schedule, and quality. It is worth stressing the importance of acknowledging the typical features of refurbishment projects (e.g. short construction timeframes, high number of constraints, uncertainty and variability) as they can be also seen as root cause of problems found in those projects (e.g. variation in the lead time, difficulty to synchronise crews on site). It is argued that those peculiarities should be taken into account when selecting solutions for production management because they create management challenges (i.e. need to manage complex, uncertain, and quick projects) that are not appropriately addressed through traditional managerial practices. Indeed, as pinpointed by Koskela et al. (2002) the coordination of works in such dynamic project environment cannot be effectively done even with the use of highly detailed CPM schedules.

Third, the conceptual solutions were linked to practical management approaches (Table 32). For example, in order to compress lead time and reduce variability the use of Last Planner System is recommended. For increasing process transparency the use of a visual management approach is suggested. Yet, it is worth mentioning that the principles of flow are closely related (Koskela, 1992; 2000). For example, the reduction of the share of non-value adding activities and the mitigation of variability contribute to compressing lead time whereas the compression of time, in turn, forces the reduction of inspection, move, and wait time. Therefore, an additional column named 'associated principle' was added to the Table 32 in order to show those connections.

The fourth step involved the proposition of candidate solutions as countermeasures for addressing the root causes of problems in refurbishment projects (Table 33). The author deemed the compression of lead time and the reduction of variability as the most powerful principles of production management for driving improvements in refurbishments. The latter is instrumental for tackling the uncertainties related to the existing asset, and for supporting the management of constraints related to the existing facility and production phase, whereas the former is appropriate to a project environment normally pressed for time to avoid causing problems to the users of the existing building. The guidelines, best practices, tools and techniques associated to those conceptual solutions (Table 32) are the means for supporting the application of those principles in refurbishment projects. Figure 43 shows where the tables cited earlier sit in the proposed framework.

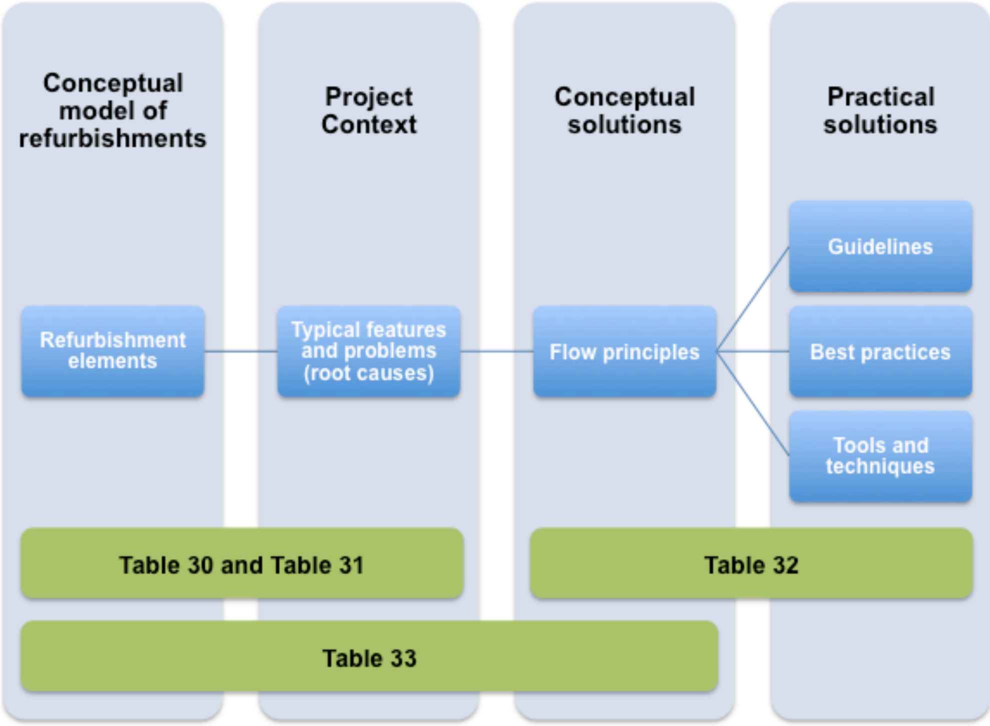

Figure 43 – Tables created to support the framework of managerial solutions

In terms of practical implementation, the Last Planner System should be the starting point as this tool has embedded in its design several managerial practices aligned with the principles cited above such as uncertainty and variability reduction, collaboration, engagement, early involvement of project participants, etc. Besides, as demonstrated in the empirical study, the use of Last Planner produces tangible results such as improved coordination, reduced disruptions in the workflow on site, and lead time compression.

Lastly, it is worth mentioning that the other principles of flow and their related practices should not be discarded but seen as enablers of improvements. For example, in order to compress lead time one has to reduce the share of non-value adding activities (e.g. move and wait time). These, in turn, can be supressed by increasing process transparency (e.g. flowcharting processes). For reducing variability, the simplification of production (e.g. by minimising the number of building components through prefabrication) is recommended. Therefore, the author encourages the application of flow-concept related principles and their associated practices for improving production management in refurbishments. It is argued that a management approach based on those principles and managerial practices will lead to better project results.

Table 31 – Root cause analysis of typical problems in refurbishment projects

Refurbishment basic elements	Problems	Root causes
Existing Asset	Lack of an appropriate understanding of the existing building Late discovery of pre-existing conditions (after design decisions had been made), therefore causing negative design iterations and rework Hazardous material (e.g. asbestos) might be encountered in the existing building Project scope can be unclear due to limited information about the existing asset	Use of inappropriate managerial practices (i.e. poor building surveying) and lack of understanding regarding the nature of refurbishment projects (i.e. poor building surveying is detrimental to production performance)
	Late involvement of stakeholders (i.e. no input of contractors and subcontractors in the building surveying), hence causing design-related rework. As-built drawings are often unavailable and when they are available, usually they are inaccurate	Use of inappropriate managerial practices (e.g. lack of integration of production teams in the building surveying process, poor practice regarding as-built drawings)
Construction Tasks	Wastes in production (e.g. waiting time, disruptions in the workflow, rework, downtime, high level of work in progress, unnecessary transport, etc.) Inefficient communication, coordination, and collaboration among the project team Difficulty to synchronise crews on site Delays in material delivery Poor performance in terms of cost, schedule, and quality in comparison with new building projects	Use of inappropriate managerial practices (e.g. highly detailed CPM plans, no contractor input on planning, thermostat model of control, etc.)
	Variability (unforeseen works and variation in the quantity of works, variation in the lead time) Unknowns on site more prominent. Discovery of unforeseen conditions continue to happen during the construction phase	Use of inappropriate managerial practices (e.g. poor building surveying) / typical features of refurbishment projects
	Short construction timeframes due to interference with building occupation and operation High number of project's constraints such as space limitations (e.g. storage, new equipment, construction), restricted access, uncertainties on the condition of the existing asset, pollution control, etc.	Typical features of refurbishment projects
Operations in the existing building	Lack of integration between design, construction, and operations	Use of inappropriate managerial practices (e.g. no input from production and facilities management teams in the design stage)
	Operational constraints related to the existing facility. Need to interface with users of the building Dangerous work (e.g. project involving demolition). Safety issues due to the interface of workers with existing operations in the building and users Tenants (lack of compliance to agreed dates, late design change requests)	Typical features of refurbishment projects

Table 32 - Connection between conceptual and practical solutions

Flow principle	Associated principle	Guidelines	Best Practices	Tools and techniques
Reduce the share of non-value adding activities (waste)	Compress lead time	Work with people skilled in refurbishments	Structured and collaborative preplanning process	Production System Design
	Increase transparency	Foster collaboration, engagement, and early involvement	Integration of internal clients during the design development	Last Planner System
			Effective and constant communication with the users of the building	Visual Management (e.g. flowchart processes)
				Multiskilling
				Cellular Manufacturing
Compress lead time	Reduce the share of non-value adding activities	Work with people skilled in refurbishments	Long term relationship with people skilled in refurbishments	Last Planner System
	Reduce variability	Foster collaboration, engagement, and early involvement	Maintenance of essential services in the existing building	Line of balance
				Benchmarking
Reduce variability	Simplify	Reduce uncertainty	Collaborative site pre-inspections	Production System Design
	Increase transparency	Provide contingencies	Early identification of project constraints	Last Planner System
		Safeguard users and operations in the existing building	Daily site visits	Prefabrication / Standardisation
			Prototyping	
Simplify	Reduce the share of non-value adding activities	Work with people skilled in refurbishments	Standardisation of design features	Production System Design
		Foster collaboration, engagement, and early involvement	Standardisation of material specifications	Prefabrication / Standardisation
				Multiskilling
				Cellular Manufacturing
Increase transparency			Use of visual aids to improve communication and decision-making	Visual management
			Visual controls	5S
Increase flexibility	Compress lead time			Modularisation
	Increase transparency			Mass customisation
	Simplify			Multiskilling

Table 33 – Countermeasures to address the root causes of typical problems in refurbishment projects

Refurbishment	Root causes of typical problems in refurbishments	Countermeasures from a lean perspective
Existing asset	Use of inappropriate managerial practices (e.g. poor building surveying) Lack of understanding on the nature of refurbishment projects (e.g. uncertainty and variability is neglected by managers)	Reduce variability
Construction Tasks	Use of inappropriate managerial practices (e.g. use of highly detailed CPM schedules) Typical features of refurbishment projects (e.g. high uncertainty and variability, short timeframes)	Compress lead time and reduce variability
Operations in the existing building	Use of inappropriate managerial practices (e.g. lack of integration of production teams in design stage) Typical features of refurbishment projects (e.g. high number of constraints)	Compress lead time and reduce variability

5.3.2.4 Second version of the method

The second version of the method for construction management in refurbishment projects is presented as a sequence of eight steps as illustrated in Figure 44.

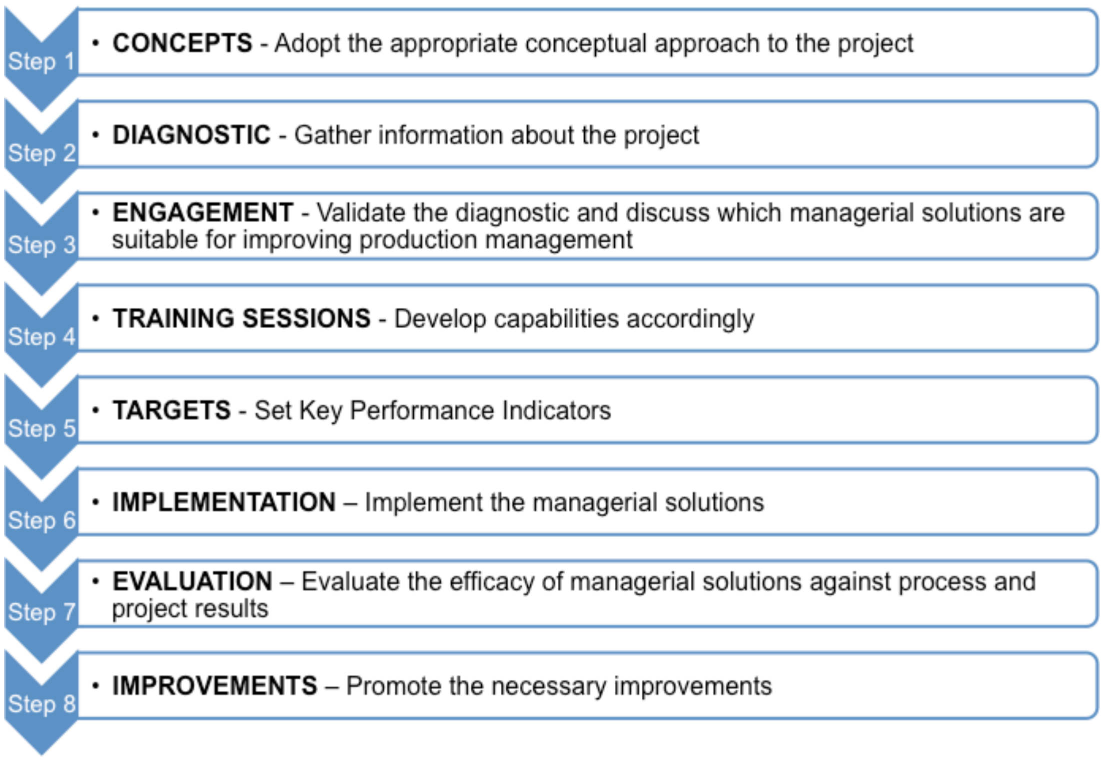

Figure 44 - Second version of the method

The increase in the number of steps of the method is one of the main differences in comparison with the first version of the artefact, i.e. it went from four to eight. This alteration was made in order to improve the implementation process of the method. Another important difference is the clarification on the criteria for selecting the candidate solutions for production management in refurbishment projects, which was not defined when the first version of the method was devised. This is a key improvement made in the design of artefact because it addresses the aim set for this investigation, i.e. it provides guidance for practitioners to select appropriate approaches of production control. It is also noteworthy the addition of two dimensions on the framework for characterisation of refurbishment projects as a result of the feedback from practitioners in the third empirical study. Next, further details on each step of the method are presented.

5.3.2.4.1 Step 1 – Concepts

The adoption of an appropriate conceptual approach is the starting point of the method. This refers to the acknowledgment of the basic features of refurbishments. As illustrated in Figure 40, these projects can be conceptualised in three parts: the existing asset, the construction tasks, and the operations in the existing building. These elements are interconnected, which means that if one wants to perform works on site effectively, then a deep understanding of the existing asset, along with the proper consideration of constraints related to the operations in the building are primary. In other words, the lack of integration between those parts can be detrimental to project performance. It is argued, therefore, that approaching refurbishments from these three perspectives supports an effective construction management, hence leading to better project results. Yet, it is noteworthy that there are circumstances in which projects can be conceptualised in two parts only. For example, in projects that the operations in the existing building are non-existent (e.g. phase 1A of the study addressed in this chapter) a two-part conceptualisation should be adopted. Finally, besides increasing awareness of project participants on the nature of refurbishments, it is argued that the conceptual model can facilitate the understanding of the subject for academics and practitioners as well as serving as a reference basis for improvements.

5.3.2.4.2 Step 2 – Diagnostic

This step is based on the notion that understanding the project environment is essential for the management of complexity and uncertainty inherent to refurbishments. The framework for characterisation of refurbishments (Figure 41) serves as means for carrying out this diagnostic. The collaboration of representatives of every organisation involved in the project is necessary to address the dimensions considered in the framework. This is a key step of the method as it provides information that serve as inputs for managers to decide on which production management approach is adequate for a given refurbishment project.

5.3.2.4.3 Step 3 – Engagement

The objective here is to engage project participants in the discussion on which managerial solutions are appropriate to be implemented in the refurbishment. The information collected through the diagnostic conducted previously has to be validated with the team to ensure decisions are based on accurate data. Representatives of every organisation involved in the refurbishment should work collaboratively to ensure different perspectives are considered.

The framework and tables presented in section 5.3.2.3 should be used in this meeting as supporting materials as they illustrate the connection between the refurbishment context, and the approaches of production control deemed as appropriate for this particular setting. The idea is to share with project participants the typical features as well as problems found in refurbishments and show the root causes of those problems (Table 30 and Table 31). Yet, the aim is to make clear that the management approach to be defined should account for the three parts of refurbishment (step 1) and be primarily based on the principles of lead time compression and variability reduction (Table 33). The managerial solutions associated to those principles (Table 32) serve as the starting point to the person who is going to lead the meeting. As mentioned in the previous chapter, this person should have knowledge on lean construction since this is the management approach upon which the tools and techniques proposed are based.

5.3.2.4.4 Step 4 – Training sessions

The development of capabilities of project participants is primary for allowing an adequate implementation of managerial solutions. It should be done in accordance with the decisions made during the engagement phase. A gradual approach is suggested for the delivery of training sessions in order to avoid demotivation of people not familiar with lean principles, tools, and techniques. This should be done in conjunction with the application of practical solutions in real projects to facilitate understanding of concepts learned in the classroom.

5.3.2.4.5 Step 5 – Targets

Key performance indicators (KPI) are used in measuring performance at process and project levels. KPIs should be set for the three parts of refurbishments as per the conceptual model and be aligned with the principles of production management endorsed in this thesis. Project features might also influence the definition of KPIs. For example, the interference with the existing operations in hospitals must be kept to a minimum level so one might keep track of disruptions caused to users of the building, while in retrofits the measurement of sustainable targets makes more sense. The diagnostic conducted previously (step 2) can be helpful in defining indicators. KPIs can be also useful in evaluating the efficacy of managerial solutions in the achievement of process and project objectives. Lastly, it worth mentioning that KPIs should be set with project participants to make sure they are aware of and committed to the targets set.

5.3.2.4.6 Step 6 – Implementation

Once the project context is understood, the production management approach defined, the project participants properly trained, and the targets set at process and project levels, then the implementation phase can begin. It should be planned in order to be effective. A clear definition of roles and responsibilities is primary for the success of the implementation of the managerial practices selected by the team. Equally important is the appointment of a person with knowledge on lean to lead this process (e.g. project manager or consultant).

5.3.2.4.7 Step 7 – Evaluation

This step is based on the notion that every managerial solution tested in a refurbishment project needs to be evaluated in terms of its utility for improving production management and for enhancing project results. It aims at assessing the applicability of lean principles in the context of refurbishments. This assessment should be conducted against the targets set. It will help managers to better understand the benefits as well as the implementation issues (i.e. enablers and barriers) of utilising lean methods in such particular settings.

5.3.2.4.8 Step 8 - Improvements

The eighth step of the method aims at improving the production management approach adopted in a given refurbishment project. This task is based on the evaluation carried out in the previous step. Managers should promote meetings with project participants to discuss on how to improve the management of the project. This might involve adaptations to managerial tools and techniques in order to suit the project context as reported in the third empirical study (Table 29). Ultimately, the idea is to reflect on the implementation and promote changes in the management approach in order to enhance project performance.

Chapter 6 Artefact evaluation

The evaluation of the method proposed in the thesis is described in this chapter (Figure 45). A focus group was organised with experienced practitioners on refurbishments to evaluate the utility of the artefact. The feedback obtained during the meeting led to refinements in the artefacts devised throughout the study, hence improving the design of the method. The final version of the method is described after the presentation of the outcomes of the focus group. The scope of applicability of the artefact is examined at the end of the chapter.

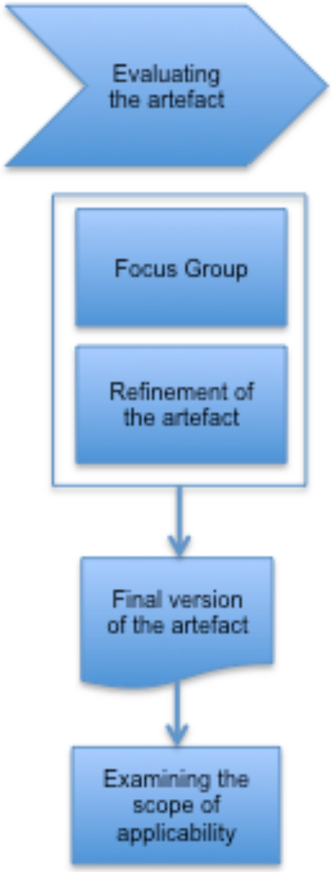

Figure 45 - Research process adopted for evaluating the artefact

6.1 Focus Group - Design

The focus group was carried out in partnership with a Norwegian contractor in June 2015. This company is one of Scandinavia's largest construction and property development companies with decades of experience in delivering refurbishment projects across several market sectors. This organisation was also chosen due to its involvement with the philosophy of production used as a reference basis in this research, i.e. lean construction. The participants of the focus group were selected based on their knowledge and practical experience in the topic addressed in the research. Yet, in order to allow the evaluation of artefact from different perspectives the author decided to invite people who worked in different positions in the company (Table 34).

Table 34 - Focus Group attendees

Participant	Job function	Experience in Refurbishments (years)
1	Department Manager	10
2	Department Manager	8
3	Project Leader	12
4	Site Manager	2
5	Foreman	9

Department managers are managers who oversee the work developed by project leaders, hence they are involved in the management of several projects. The latter are responsible for managing one project at a time and have overall responsibility for the execution of refurbishment projects, which includes tasks such as production planning and control, site logistics, and management of stakeholders. Site managers are responsible for supervising construction sites, managing contractors, health & safety, quality, and programme. Foreman is the manager of a discipline, for instance, the mechanical and electrical crew.

The focus group aimed at evaluating the second version of the method. Nonetheless, it is worth mentioning that it took place before the end of the third empirical study when the criteria for selecting the candidate solutions for production management in refurbishment projects were not fully developed, as presented in the previous chapter. The focus group was carried out between the workshop on continuous improvement, which was conducted after the first phase of the retrofit (phase 1A), and the second phase of the project (phase 1B). The author deliberately made this decision because at that point he did not have the confirmation on when the second phase of retrofit (phase 1B) would take place and if that would fit into the research timeframe. Besides, he did not want to waste the opportunity to get the artefact evaluated by such experienced practitioners. In order to clarify the sequence of events mentioned above a timeline is presented in Figure 46.

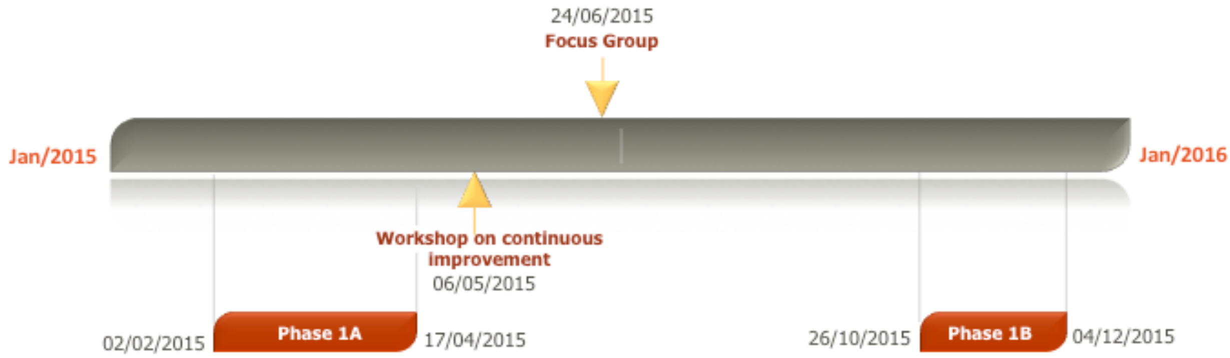

Figure 46 – Overlap between the third empirical study and focus group

The following goals were set for the focus group:

- Evaluate the conceptual features of the artefact;
- Evaluate the applicability of the artefact within the organisation.

In order to achieve the goals the author structured the meeting in three stages. First, the research was introduced to the attendees and the objectives of the focus group were explained. Second, the method devised in thesis was presented and the participants evaluated its conceptual features. Third, findings from the third empirical study were shared with the participants with the purpose of showing a real-world implementation of the method. This was followed by the evaluation of the practical features of the artefact. The agenda set for the focus group is presented in Table 35.

Table 35 – Focus Group agenda

Stage	Agenda	Schedule
1	Introduction	13:00 – 13:05
	Objectives of the focus group	13:05 – 13:10
2	Presentation of the method proposed in the thesis	13:10 – 13:30
	Discussion – Evaluation of the method (conceptual features)	13:30 – 14:15
	Break	14:15 – 14:30
3	Case study – Implementation of the method in a retrofit project	14:30 – 14:45
	Discussion – Evaluation of the method (practical features)	14:45 – 15:30
	Closing remarks	15:30 – 16:00

The discussions that took place during the focus group were guided by questions prepared by the author before the meeting. These are presented in the next sections.

6.1.1 Conceptual features of the method

The evaluation of the conceptual features of the artefact addressed the conceptual model of refurbishments, the framework for project characterisation, and the steps of the method. The candidate solutions for production management identified earlier in the research were introduced to the participants but they could not be evaluated due to limited time.

6.1.1.1 Conceptual model of refurbishments

The conceptual model shown in Figure 47 was introduced to the participants of the focus group during the presentation of the method. The author explained how it was developed and stressed the purpose of the artefact in the context of the research.

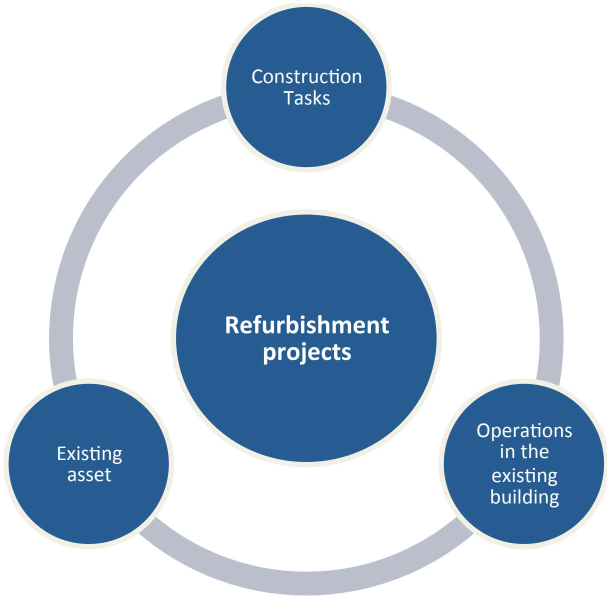

Figure 47 – The conceptual model of refurbishment projects

The following questions guided the discussion on the conceptual model of refurbishments:

- Does the conceptual model of refurbishments devised in the thesis contain all key elements that should be considered in the construction management of refurbishment projects?
- Should any of these elements be removed? Why?
- Are there other key elements that should be added? Why?

6.1.1.2 Framework for characterisation of refurbishment projects

The framework presented in Figure 48 is the version refined as per the feedback obtained during the workshop on continuous improvement carried out throughout the third empirical study. In order to introduce the artefact, the author described its aim, the rationale behind it, and explained the meaning of each dimension addressed in the framework.

Project Characteristics	Industry Sector
	Project
Design intent	
Project driver	
Scope of works	
Typical problems	
Root causes	
Sequence of works on site	
Organisational structure	
Building information	
Building occupation	

Figure 48 - Framework for characterisation of refurbishment projects

The following questions guided the discussion on the criteria for project characterisation:

- Are the dimensions addressed in the framework appropriate to be used as an initial diagnostic in a refurbishment project?
- Is there any dimension that should be added or removed?

6.1.1.3 Steps of the method

The steps devised for the implementation of the second version of method are presented in Figure 49. The author described to the participants the evolution of the artefact from four to eight steps and explained the role of each step for achieving the purpose of the method.

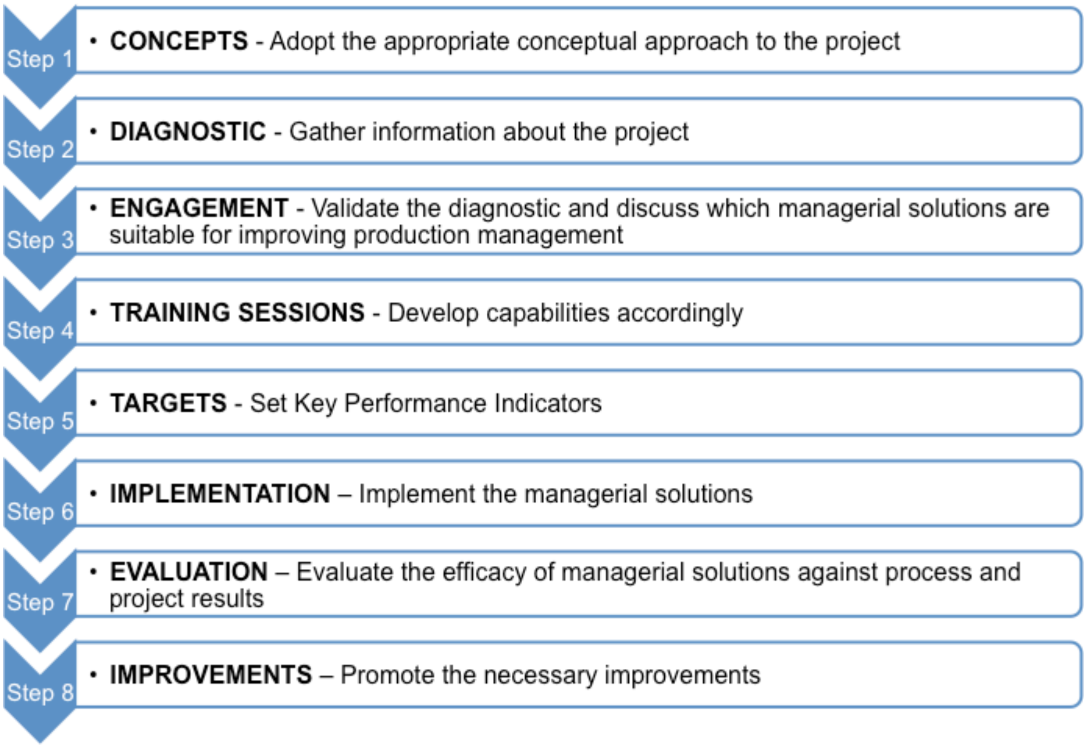

Figure 49 - Steps for implementing the second version of the method

The following questions guided the discussion on the steps of the method:

- Are the steps sufficient to apply the method?
- Are there any steps that should be added, merged, or removed?
- Is the role of each step clear?

6.1.2 Practical features of the method

The evaluation of the practical features of the method focused on the applicability of the artefact within the organisation. This discussion was carried out after the presentation of a case study showing the practical implementation of the artefact. The author explained how the method was applied in a retrofit project and described the managerial tools and techniques utilised during the implementation as well as the benefits achieved. The evaluation was guided by the following questions:

- Would you apply this method in your company to manage the construction of refurbishment projects? Why?

In case YES, the participants were asked:

- Would the application of the method require changes in the company and its processes? What changes?

In case NO, the participants were asked:

- What are the reasons for not implementing it?

Yet, an additional question was asked at the end of the discussion on practical features:

- What are the strengths and weaknesses of the method as presented?

6.2 Focus Group - Outcomes

The presentation of the results of the focus group follows the structure set in the agenda presented earlier, namely, first the evaluation of the conceptual features are reported and then the practical features are addressed.

6.2.1 Evaluating the conceptual features of the method

6.2.1.1 Conceptual model of refurbishment projects

The first artefact evaluated was the conceptual model of refurbishment projects (Figure 47). All attendees considered the artefact as a precise representation of a refurbishment project and one participant underlined the simplicity of it as illustrated as follows:

> *"I think it is a good model. Keep it simple".*

There was also a consensus among the participants on the importance of integrating the three elements shown in the conceptual model in order to achieve an effective construction management, hence better project results. On this regard, a manager contended that the company should improve its approach regarding the existing asset, namely, it should invest more resources for better understanding the condition of the existing building in order to improve the performance of works on site. Furthermore, the participants argued that the conceptual model could be helpful to manage clients' expectations. As quoted below, it would be beneficial if clients could understand the constraints related to the existing asset:

> *"Clients are normally not aware of project constraints so they keep requesting impossible things… if clients are involved in the building surveying process, which is very important, then through the surveying process you can reveal what is possible and what is not possible given the structure of the building… This could avoid waste in design and construction".*

One participant argued that the conceptual model could be also used as a framework for underpinning the quality management system used by the company. Basically, the quality system sets out guidelines in terms of things that have to be in place in every project. This is illustrated through the following quote:

> *"I think we should take a good look into our quality system and try to place the guidelines we have based on your conceptual model... we have many tools in our quality system, we could use the method to structure these tools in a proper way".*

The comment above demonstrates the potential of utilising the conceptual model as a reference basis for improvements. Yet, the artefact was deemed innovative and useful for increasing awareness on the characteristics of refurbishments as illustrated as follows:

> *"It is a new way to attack refurbishment projects… I think the conceptual model is helpful to develop a specific understanding of each project".*

Regarding the three parts considered in the conceptual model, one attendee noted that operations in the existing building do not always exist. This confirms a statement made earlier in the thesis, namely, there are circumstances in which refurbishment projects can be conceptualised in two parts only. Yet, there was no request for removing or adding any element displayed in the current version of the artefact, but one participant suggested that the artefact's design could be altered to show the connection between the three parts addressed in the conceptual model. It was suggested:

> *"One thing that maybe is lacking in the conceptual model is a clear link showing the involvement between the 3 elements of refurbishment".*

6.2.1.2 Framework for characterisation of refurbishment projects

The participants approved the dimensions addressed in the framework. They said it is a good list for promoting an initial understanding of the refurbishment since it covers key aspects of the project. The following quote illustrates that:

> *"I think it (framework) covers (refurbishment project) very well".*

The idea of knowing more information about the project beforehand was appreciated by the foreman. He highlighted that it is very important for the department managers to gather appropriate information before sending people like him to construction sites.

The attendees suggested new dimensions to be added in the artefact. Three people argued that information about the client should be considered in the framework. They contended that it could help in delivering value as demonstrated in the quote as follows:

> *"If you want to deliver value for the client you have to know more information about him/her".*

The participants argued that information on budget should be also added in the framework since it is an important element of the project. Besides, one person suggested the addition of a dimension regarding health and safety due to the reason described in the quote below:

> *"Health and safety is a big part of what we are doing… the goal of the company is to have zero accidents so it would be good to have it considered in the framework".*

6.2.1.3 Steps of the method

All participants agreed that the eight steps shown in Figure 49 are sufficient to apply to the method proposed in the thesis. However, there was also a consensus on the need of dividing those steps into two groups as follows:

- Planning; and
- Implementing and improving.

Instead of presenting the method as a linear sequence of steps (Figure 49), the participants contended that the artefact could be presented as two distinct but connected stages. The first one (planning) should address steps 1, 2, 3, 4, and 5, and the second (implementing and improving) steps 6, 7, and 8. Also, due to the dynamic nature of projects, they argued that those stages should be carried out several times during the refurbishment in order to account for the changes that are likely to happen throughout the project. The quotes below show the importance of refreshing the information about the diagnostic (step 2):

> *"It (diagnostic) could be carried out or updated according the different phases of the project (e.g. phase 1, phase 2) as more companies are likely to join the refurbishment as well as more information is likely to be available as the project progresses or more access to certain areas of the building is granted".*

> *"You have to do it at the beginning of the project with the start team, and then you have to do it again when you add one more persons to the team, and then you have to do it again when you add another company, and then you have to do it again when you go in to a new area of the building".*

Following the same line of thought, they also mentioned that other steps of the method would also need to be revisited as the project develops such as the engagement of people in making decisions (step 3), the development of extra training sessions (step 4) to attend the latest demands of the project, and the setting of new targets (step 5) to reflect the needs of different project phases.

Regarding steps 6 (implementation), 7 (evaluation), and 8 (improvement), the attendees kept the same view they had with regards the steps related to the planning stage, namely, they argued that the implementation of the method should be carried out in cycles in order to address the changes that are likely to occur during the project.

Also, the participants contended that steps of the method could help to formalise decisions made throughout the project. They argued that it could improve communication among stakeholders, especially in projects that several handovers are planned. The quote below illustrates that:

> *"If you have some short descriptions of what you've been through, the thoughts you had, the discussions you had based on those different steps it is easier to handover the project to another party than otherwise… I think it is a very structured way to do it".*

6.2.2 Evaluating the practical features of the method

The participants were positive when asked if they would apply the method proposed by the author for managing construction in refurbishment projects developed by the company. They argued that some steps of the method are already in place in the organisation (e.g. training sessions, set key performance indicators, implementation, improvements), but not in such structured way.

Three comments were made with regards to changes needed for implementing the method in the company:

- Involvement of project stakeholders (e.g. designers, suppliers, subcontractor, etc.);
- Appointment of a person responsible for leading the implementation of the method;
- Investment of resources (i.e. time) necessary to implement the steps of the method appropriately.

In terms of the strengths of the method, there was a consensus among the participants on the structure of the artefact. They said that the method is a structured way to manage a refurbishment project and that it could be used to ensure consistency and standardisation in the management of different projects across the company. The following quote illustrates it:

"You have conceptualised this process and you have standardised in some steps and I think that is the way we have to go, we have to go this way. I think we have to do it".

In terms of the weaknesses of the artefact, one participant said that the implementation of all steps of the method might be an overwhelming task.

6.3 Refining the artefact

The focus group was instrumental for promoting refinements to the method proposed in the thesis. The author addressed the recommendations suggested by the participants as indicated in the following sections.

6.3.1 Conceptual model of refurbishment projects

In order to stress the relationship between the three parts depicted in the conceptual model the author decided to add arrowheads in the circle connecting those elements. The final version of the artefact is presented in Figure 50.

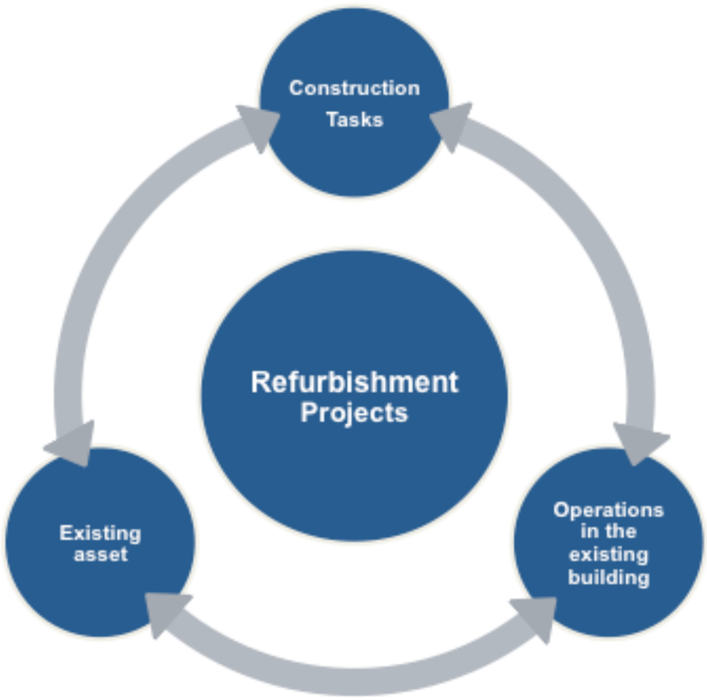

Figure 50 - Final version of the conceptual model of refurbishment projects

The conceptual model of refurbishment projects is a framework that should be used to support an appropriate construction management. It represents the basic nature of refurbishment as it shows clearly the interconnection between the existing asset, the works on site, and the operations in the existing building. These three elements interact with and affect one another in significant ways. For instance, the knowledge on the existing asset and the operations in the building are essential for an improved performance in the execution of construction tasks. A poor understanding of the condition of the building being refurbished, as well as the on-going operations, can cause design-related rework, disruptions in the workflow on site, and ultimately schedule and cost overruns. The construction tasks, in turn, can cause disturbances to users of the building if not managed properly. For instance, this is likely to happen when the condition of the existing asset is not well assessed and unknowns that could be anticipated affect the continuous flow of works on site, hence annoying users and causing disruptions in the operations in the building. Therefore, if one wants to improve performance of production in refurbishment projects, the management of those three basic elements displayed in the proposed conceptual model should be integrated.

6.3.2 Framework for characterisation of refurbishment projects

Three new dimensions were added to the framework for project characterisation in order to address the recommendations made during the focus group. They refer to information on budget, client, and health and safety (Figure 51).

Project Characteristics	Industry Sector
	Project
Design intent	
Project driver	
Budget	
Client	
Scope of work	
Typical problems	
Root causes	
Health and safety	
Sequence of works on site	
Organisational structure	
Building information	
Building occupation	

Figure 51 – Final version of the framework for characterisation of refurbishments

Budget refers to the amount of money allocated for the execution a given refurbishment. It can be shown as a total sum or in portions related to phases of the project. The dimension on client aims at capturing information on customer requirements in order to allow the understanding as well as the fulfilment of those needs by the project team. Health and safety concerns the policies, regulations, and procedures set to ensure safety and wellbeing in the project. The participants approved the other dimensions addressed in the framework, thus these were not altered or removed.

The framework for project characterisation aims at supporting the management of complexity inherent to refurbishments. Furthermore, it plays the role of providing common ground as it serves as the starting point for the discussions and interactions among project participants. As noted earlier, this is a precondition for enabling an effective communication and collaboration among stakeholders, which is essential for the practical implementation of modern managerial practices such as the ones proposed in this thesis.

Finally, it is worth mentioning that the use of framework is not meant to provide a detailed assessment, but rather a simplified diagnostic of the project situation for ensuring everyone involved is aware of project's goals, specifications, organisational structure, limitations, uncertainties, etc. It is argued that its use enables effective decisions on the management system to be implemented in a refurbishment project, hence supporting improvements in project results.

6.3.3 Candidate solutions for production management in refurbishment projects

As mentioned earlier, the candidate solutions for production management identified during the research were introduced to the participants throughout the focus group, but they were not evaluated because of limited time. The author argues that this fact is not an issue that invalidates the work developed in the study as in his opinion the best way to evaluate the utility of those managerial practices is through practical tests. Indeed, the third empirical study was instrumental in demonstrating the utility of principles of production management suggested in the research such as variability reduction and lead time compression. Besides, practices such as early identification of project constraints, collaboration, and engagement of project participants in the production planning process were also useful for improving project performance. The successful application of the Last Planner System of production control is also worth mentioning. Therefore, it is argued that the framework of managerial solutions proposed in the previous chapter should be used as the reference basis for the management of construction in refurbishment projects since it indicates appropriate approaches of production control.

6.3.4 Final version of the method

Based on the recommendations proposed during the focus group, the design of the method for construction management in refurbishment project was altered. The final version of the artefact is presented as two distinct but connected stages as shown in Figure 52.

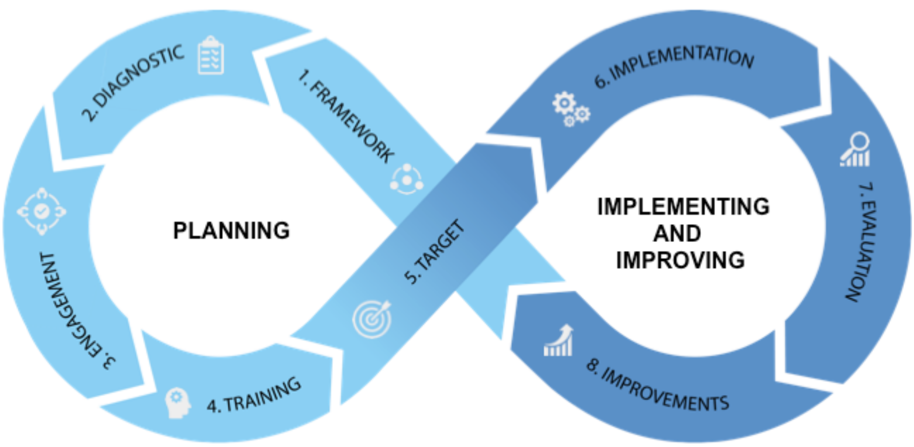

Figure 52 - Final version of the method for construction management in refurbishment projects

The final version of the method can be considered as a natural progression from the second version of the artefact. It contains the same eight steps as presented in the earlier version with refinements made as a result of the focus group. The main improvement refers to the creation of two distinct implementation stages as per the nature of the activities carried out in each step of the method. A few minor alterations have also been made in components of the method in order to enhance its effectiveness, for instance, arrowheads have been added in the circle connecting the three parts depicted in the conceptual model of refurbishment projects to show clearly the relationship between those elements and three new dimensions have been added in the framework for project characterisation for covering important issues in refurbishments as per the feedback obtained in the focus group. Next, further details are presented on each step of the method.

6.3.4.1 Planning stage

The planning stage comprises the five initial steps of the method. As pointed out during the focus group, the steps number two, three, four, and five are likely to be carried out several times in order to catch up with the changes that might happen to the project environment. The step number one is embedded in the framework for characterisation of refurbishment projects, thus it should be also revisited when the diagnostic gets reviewed.

6.3.4.1.1 Step 1 – Framework

The conceptual model of refurbishments devised in the thesis (Figure 50) is the conceptual framework that underpins the method for construction management in refurbishment projects. It shows the three basic parts of a refurbishment (i.e. the existing asset, the construction tasks, and the operations in the building) that need to be taken into account for supporting an effective construction management. The lack of integration between those parts is detrimental to project performance. This conceptual framework might be adapted to reflect a specific project situation, namely, one should select a two-part conceptualisation when there are no operations on-going in the existing building.

It is worth mentioning that in the previous version of the method, this step was named as ‘concepts’. However, during the research it became clear the role of the conceptual model as a conceptual framework that is used for supporting an effective construction management in refurbishment projects. This was noted during the workshop on continuous improvement in the third empirical study when the conceptual model was used as a framework for locating the problems faced throughout the retrofit. Besides, the author noted that practitioners understand better the term ‘framework’ than ‘concepts’. Therefore, this step was renamed to ‘framework’.

6.3.4.1.2 Step 2 – Diagnostic

This step is based on the notion that understanding the project environment is essential for the management of complexity and uncertainty inherent to refurbishments. Also, it helps in the definition of the management system since it provides information that serve as inputs for managers to decide on which production management approach is adequate for a given refurbishment project. The diagnostic should be conducted through the framework for project characterisation devised in the thesis (Figure 51). In order to enable the completion of all dimensions addressed in the framework as well as ensuring different perspectives are considered, the collaboration of participants of the project is required.

6.3.4.1.3 Step 3 – Engagement

The engagement of project stakeholders in the discussion on which managerial solutions are appropriate to be implemented in a refurbishment is recommended. It is argued that the participants are more aware of and committed to a management approach when they take part in the decision-making process. The information collected through the diagnostic cited previously serves as the input for this discussion. In addition, the framework and tables presented in section 5.3.2.3 of the thesis should be also used in this meeting as supporting documents as they illustrate the connection between the refurbishment context and the approaches of production control deemed as appropriate for this particular setting. The idea is to share with project participants the typical features as well as problems found in refurbishments and show the root causes of those problems. As mentioned earlier, the aim is to ensure that the management approach applied in the project addresses the three parts of refurbishment and be primarily based on the principles of lead time compression and variability reduction. The managerial solutions linked to those principles should be seen as practical means for implementing those conceptual ideas.

6.3.4.1.4 Step 4 – Training sessions

Training sessions are designed to build capabilities of project participants for enabling an appropriate implementation of managerial solutions. The content of those training sessions should follow the decisions made during the engagement phase. For avoiding demotivation of people not familiar with the lean theory, tools, and techniques, a gradual approach in the delivery of the sessions is recommended. Equally important is the application of the knowledge taught in the classroom in real projects in order to facilitate the understanding of the concepts learned.

6.3.4.1.5 Step 5 – Target

The use of key performance indicators (KPI) is recommended for measuring performance at process and project levels. They should be set for the three parts of refurbishments as per the conceptual model and be aligned with the principles of production management advocated by the author, namely, the flow-concept related principles. The diagnostic mentioned in the second step of the method should serve as a supporting document in the definition of KPIs because it identifies project features that might influence what needs to be measured. KPIs can be also useful in evaluating the efficacy of managerial solutions in the achievement of process and project objectives. Lastly, KPIs should be set in collaboration with project participants to make sure they are aware of and committed to the targets set.

6.3.4.2 Implementing and improving stage

The second stage of the method comprises the implementation of the managerial practices selected in the planning stage as well as the evaluation and improvement of those solutions. It is worth mentioning that it is not necessary to wait until the end of the project to evaluate and improve the process. In other words, if in the first stages of the implementation some deviations happen, then there should be learning cycles to get the project back on track.

6.3.4.2.1 Step 6 – Implementation

In order to be effective, the implementation of the managerial solutions selected in the planning stage should be planned. Project participants should be involved in the application of the method. Roles and responsibilities should be clearly defined. The appointment of a person responsible to lead the implementation of the artefact is required to make sure all steps are performed appropriately. As mentioned earlier in this thesis, this person should have knowledge on lean construction since this is the management philosophy upon which the managerial solutions suggested in the thesis are based.

6.3.4.2.2 Step 7 – Evaluation

The managerial solutions selected in the planning stage to be implemented in a project should be evaluated against the targets set (step 5). Managers should assess their utility for improving the performance of production and project results. Yet, the evaluation aims at evaluating the applicability of lean principles in the context of refurbishments. Furthermore, it will help managers to better understand the benefits as well as the implementation issues (i.e. enablers and barriers) of utilising lean methods in such particular project settings.

6.3.4.2.3 Step 8 – Improvements

The eighth step of the method aims at improving the production management approach adopted in a given refurbishment project. This task is based on the evaluation carried out in the previous step. Managers should promote meetings with project participants to discuss how to improve the management of the project. This might involve adaptations to managerial tools and techniques in order to suit the project context. Finally, the idea is to reflect on the implementation and promote changes in the management approach in order to enhance project performance.

6.4 Examining the scope of applicability of the artefact

Are the artefacts devised in this study applicable to every refurbishment context? Can any company in any country using whichever managerial system implement the proposed method successfully? Are there basic requirements for using the artefact? These questions are the subject of this section. The analysis of the scope of applicability of the method was based on three sources of evidence, namely, the practical test of the artefact carried out during the third empirical study, the evaluation conducted in the focus group, and the reflection of the author on findings from those evaluations.

The artefacts devised in this research were evaluated in two different contexts. The first evaluation occurred during the execution of a retrofit project in Northern Ireland where the author had the chance to implement the initial version of the artefact and obtain feedback on its utility. The second evaluation took place in a focus group carried out in partnership with a Norwegian contractor where the author presented the artefact to practitioners skilled in refurbishment projects. On both occasions, no major objection was raised with regards to the overall applicability of the method. On the contrary, evidence from those evaluations demonstrates that the artefact is applicable in different countries. Evidently, this analysis is limited to the two evaluations carried out during the study, yet the author argues that the method has the potential to be at least tested in other project contexts.

It is interesting to discuss, however, the preconditions for utilising the artefact. Throughout the research it became clear that some requirements are needed for allowing an appropriate implementation of the method and its components in other refurbishment contexts other than the ones addressed in this investigation. Those preconditions are described below.

Firstly, the appointment of a leader is recommended to ensure a successful application of the method. This person should work for the company that is leading the development of the refurbishment project, for instance, the client organisation or the main contractor. This is because those companies are more likely to interface with all stakeholders involved in the project so they can manage properly the application of the method. A company that is engaged temporarily in the refurbishment (e.g. a subcontractor responsible for fitting windows) would not be in the best position to lead the implementation of the artefact.

Secondly, a solid understanding on lean concepts and principles is necessary for the person who is going to lead the implementation of the method because this is the management approach upon which the tools and techniques proposed are based. On this regard, a lean consultant might be necessary in organisations not used to this way of work to help the leader by ensuring that the lean philosophy is adequately implemented.

Thirdly, multi-disciplinary teams are also required to enable the accomplishment of tasks prescribed in the method. The collaboration of project stakeholders (e.g. client, designers, engineers, construction manager, subcontractors, and suppliers) is essential for supporting an effective implementation of the artefact.

And finally the method proposed can be considered a new way to address the management of production in refurbishment projects, hence time might be required for companies to adapt to this innovative way of work.

Despite the preconditions stated above, it is noteworthy that further dissemination of the method in different contexts is a subject for further studies. As noted by Lukka (2003, p. 5), the potential diffusion “should not be viewed only as the task of the primary constructive researcher, but an issue for the wider practical and academic audience”.

Chapter 7 Conclusions

In this chapter, the conclusions of the research are presented. The chapter is organised in four sections. Firstly, the research problem as well as the aim and the questions set for this investigation are addressed. Secondly, the research process is summarised in view of the key elements of the constructive research approach, namely, design and evaluation. The limitations of the study are also described in the second section. Thirdly, the contributions of the study are reviewed from two perspectives, i.e. theoretical and practical. Fourthly, suggestions for future research are provided.

7.1 Addressing the research problem, the aim and the research questions

Refurbishments are complex projects. Yet, as reported in section 3.1.1.2 of chapter 3, construction companies are still using traditional practices for managing construction in this particular setting. The use of such incompatible management approach leads to waste in production and it is likely to result in poor project performance. Indeed, problems in managing refurbishments have been identified in several countries. The author argues that the underlying reason behind this troubling scenario is the lack of a theory-based construction management approach tailored to suit the basic nature of refurbishment projects. This is the research problem addressed in this investigation.

In order to tackle the research problem, this investigation aimed at a method for construction management in refurbishment projects with the purpose to improve production performance by indicating appropriate approaches of production control. This artefact was devised by using the constructive research approach. Further details regarding the design and evaluation of the artefact is provided in the next section.

Four questions were formulated to serve as guidance to the achievement of the research aim. These are addressed as follows:

- How should a refurbishment project be conceptualised for supporting appropriate construction management?

In order to support appropriate construction management, a refurbishment should be conceptualised in accordance to its basic nature. The existing asset and the operations in the existing building are the most distinguishable characteristics of refurbishments. These features are particularly important in the context of this investigation as they influence the management of construction since they tend to increase the complexity of the project. The author argues, therefore, that refurbishments can be abstracted in three parts, namely, the existing asset, the construction tasks, and the operations in the existing building. These parts are interconnected, i.e. they interact with and affect one another in significant ways. It is argued that the management of the three parts addressed in the conceptual model presented in section 6.3.1 should be integrated for supporting effective construction management, hence allowing improvements in production and project performance.

- How should a refurbishment project be characterised for providing a foundation to construction management?

The author contends that refurbishments should be seen as complex projects due to their peculiarities. The views on complexity addressed in section 3.2.1 of chapter 3 are instrumental for providing a foundation to construction management as they offer guidance for understanding and managing complex endeavours. For example, dimensions of project complexity such as the number of elements in a project and the uncertainty stemming from the project environment can be interpreted into the refurbishment context, respectively, as the number of activities to be undertaken in a project (i.e. scope of work) as well as the number of stakeholders involved (which can be shown through the organisational structure) and the unknown features of the existing asset (e.g. lack of as-built drawings). Interdependence of elements, another dimension of project complexity, can be translated as sequence of works on site. Those attributes constitute, in conjunction with the elements addressed in the conceptual model, the basic features added as dimensions in the framework for project characterisation devised in the thesis. It is contended that the acknowledgment of refurbishments as complex projects allows effective decisions in terms of production management, hence enabling better project results.

- How to apply a theory of production in the construction management of refurbishments?

The author suggests that a theory of production is applied in construction management of refurbishments through the implementation of managerial practices in line with such theory. For example, the concepts and principles of the TFV theory were successfully applied in an empirical study carried out in this research by utilising the Last Planner System as described in chapter 5, section 5.2.3.2. It is argued that this tool promotes the flow view of production through the stabilisation of works on site. It does that by reducing the variability and uncertainty inherent to refurbishments as well as by fostering collaboration and engagement among project participants. In order to clarify the link between theory and practice the author has devised a table (Table 32 presented in section 5.3.2.3) showing the connection between the TFV's concepts and principles and a number of managerial solutions, including guidelines from the literature, best practices from empirical studies, and also tools and techniques deemed as suitable to cope with the peculiarities of refurbishments.

- How to select practices for managing construction in refurbishment projects?

The selection of practices for managing construction in refurbishment projects should be based on the context of the project and on the theoretical background provided by the TFV theory of production. To this end, a framework connecting the principles of the TFV theory to managerial practices identified throughout the research has been devised. This artefact, which is presented in section 5.3.2.3 of chapter 5, is underpinned by the conceptual model proposed in the thesis and it links the features and problems commonly found in refurbishments to managerial solutions promoted in the research. It is contended that the management approach should account for the three parts of refurbishment and be primarily based on the principles of lead time compression and variability reduction. The researcher contends that these are the most powerful principles of production management for driving improvements in refurbishments.

7.2 Summary of the research process

The research process followed in this study is based on the features of the constructive research approach, also named design science research (DSR). Essentially, the DSR aims at designing and evaluating artefacts (also called constructions or solutions) with the purpose to solve relevant practical problems while contributing to theory in the field of study. Thus, the research process is recapitulated here in light of the key components of the DSR, i.e. design and evaluation. The limitations of the study are described at the end of the section.

7.2.1 Design

For designing the artefact proposed in this investigation, the researcher followed two steps. First, a relevant practical problem with potential for theoretical contribution was identified. Through an initial literature review on construction management in refurbishment projects, the author found out that refurbishments present poor performance when compared to new build projects. Moreover, as presented in section 3.1.1.2 of chapter 3, it turned out that several types of wastes occur in refurbishment sites such as waiting time, disruptions in performing tasks on site, unnecessary transport, etc. Findings implied that those problems are due to the use of practices not appropriate for managing construction in such complex project setting. From a theoretical perspective, the problem was the lack of a construction management approach based on an appropriate theory of production and tailored to suit the basic nature of refurbishment projects. It is also noteworthy the shortage of studies on construction management in the refurbishment domain, hence demonstrating the potential for developing research in that area.

Second, the author delved into the literature to better understand the problem identified previously and to identify the theoretical background that could be used to underpin the artefact. Besides construction management in refurbishment projects, subjects such as management of complex and uncertain projects, theory of production, and managerial methods for construction management were reviewed. Based on the literature review (section 3.1.1.1, chapter 3), the peculiarities of refurbishments were clarified and a conceptual model was proposed (section 4.3.1.1). It refers to an integrated view of basic elements of refurbishments (i.e. the existing asset, operations in the existing building, and construction tasks) designed for increasing awareness of project participants regarding the nature of the project, hence supporting an effective management of construction. The literature on project complexity addressed in section 3.2.1 of chapter 3, in turn, was helpful in conveying the idea that a better understanding of the project environment enables discussions and actions that support the management of complexity. The framework for project characterisation devised in the thesis (section 4.3.1.2) was built upon this notion. Finally, the literature review on theory of production (section 3.2.2, chapter 3) was fundamental in helping the researcher to pinpoint the reasons behind the failure of the traditional management approach applied in refurbishments as well as to show the theoretical background upon which the managerial practices applied in refurbishments should be based. The TFV theory of production was defined as the reference basis for driving improvements in construction management of refurbishments. In addition to the literature review, two empirical studies were carried out (section 4.2.2, chapter 4) to help the author comprehend the problem identified earlier since the existing knowledge on construction management in refurbishment projects is scarce. Through the empirical studies the researcher expanded his understanding on the typical characteristics of refurbishments, the problems faced in those projects, the methods used by companies to manage production, and he also identified opportunities for improvement as well as best practices in managing production in refurbishments. The information obtained through the literature review and the empirical studies served as inputs for the design of the first version of the method for construction management in refurbishment projects. Those inputs are described in sections 4.2.1, 4.2.2.1.6, and 4.2.2.2.6 of chapter 4.

7.2.2 Evaluation

For evaluating the applicability of the method devised in the thesis, the author implemented it through a practical test conducted in a retrofit project undertaken in phases (section 5.2, chapter 5). Such a project was considered ideal for research purposes, as the knowledge regarding the refurbishment work in one phase, could straightaway be implemented into the next one. Throughout this empirical study, the researcher collaborated closely with the project team by facilitating training sessions and production planning and control meetings. The method proved to be useful to the purpose for which it was designed, i.e. it helped managers to select suitable practices for managing production in the refurbishment. This, in turn, resulted in benefits for the project such as compressed lead time, reduced waste, smoothed workflow on site, and improved customer satisfaction. Furthermore, this test was instrumental for the refinement of the method because the author could learn from the practical implementation of the method and from the feedback obtained with practitioners on the utility of the artefact. Consequently, a second version of the artefact was created (section 5.3.2.4, chapter 5).

The improved version of the method was then submitted to an extra evaluation as described in chapter 6. This was done through a focus group carried out with experienced practitioners in refurbishments. This evaluation focused on two aspects, i.e. the conceptual features of the artefact and the applicability of the method within the organisation. The former tackled the conceptual model of refurbishments, the framework for project characterisation, and the steps of the method (section 6.2.1, chapter 6). The latter was concerned whether the practitioners would apply the proposed method for managing construction in refurbishment projects developed by the company (section 6.2.2, chapter 6). The author prepared questions for guiding the discussions throughout the focus group. This meeting was fundamental to improve the design of the artefact and to confirm its utility as well as to show the preconditions for its implementation. This evaluation led to the final version of the method (section 6.3.4), which consists of a combination of artefacts that correspond also to outcomes of this investigation. They refer to a conceptual model of refurbishments (section 6.3.1), a framework for project characterisation (section 6.3.2), and a framework of managerial solutions for production management in refurbishment projects (section 5.3.2.3, chapter 5).

The last step performed by the author was the assessment of the contributions of the method, which was done from two viewpoints, i.e. theoretical and practical. The artefacts devised in the research were discussed in relation to the existing literature on construction management in refurbishment projects and also in terms of the benefits they bring from the perspective of industry. The theoretical and practical contributions of the study are detailed after the presentation of the limitations of the research.

7.2.3 Limitations

As mentioned in the previous section, the evaluation of the method proposed in this thesis was based on data obtained from a practical test of the artefact in a retrofit project (section 5.2, chapter 5) and an assessment made via a focus group with experienced practitioners (chapter 6). Care was taken in selecting such project setting and organisation to ensure that the artefact could have the best assessment possible during the course of the research. However, the time allotted for this investigation and the availability of industry partners for fully implementing the method precluded a thorough evaluation of its impact in practice. This should be examined in further projects to corroborate the initial findings obtained in this study.

The limited time for developing the research has also impeded the evaluation of the utility of the managerial practices contemplated as candidate solutions for improving production management in refurbishment projects. Only a few practices could be assessed during the implementation of the method in the third empirical study (section 5.2, chapter 5). However, the findings indicated that there is a potential for improving performance of refurbishments through the use of appropriate methods of production control. Hence, further practical tests are encouraged.

Finally, it is worth mentioning a limitation associated to the research method adopted in the study. As mentioned by Lukka (2003), "similarly as in any small sample case study, also constructive studies typically have a limited possibility to control the examined variables, which leads to the problem of internal validity". While this limitation cannot be entirely eliminated it can be attenuated by the triangulation of methods in data collection, as it was the case in this research.

7.3 Contributions of the study

The contributions of the study are reviewed from two different viewpoints, namely, theoretical and practical. The former is focused on how the study advances the existing knowledge, whereas the latter refers to benefits from the perspective of the industry. Despite the different emphases, it is noteworthy that both contributions stem from the artefacts devised throughout the research, i.e. the conceptual model of refurbishments, the framework for project characterisation, the framework of managerial solutions, and the method for construction management in refurbishment projects.

7.3.1 Theoretical contributions

Research on construction management in refurbishment projects is scarce and has lacked a theoretical underpinning. As discussed in chapter 3, there are few studies delving into the way companies have been managing construction in such particular settings, and theory of production is a topic usually ignored by researchers who carried out research on that domain. From this perspective, this study contributes to the existing knowledge by providing a better understanding of how production is usually managed in refurbishments (section 3.1.1.2, chapter 3). It summarises, through an extensive literature review (chapter 3) and empirical studies (chapter 4), the typical features of refurbishments as well as the common problems faced in those projects and it points out their root causes by looking at underlying reasons behind such failures, namely, the poor understanding regarding the nature of refurbishments and the lack of a sound theoretical foundation (section 3.1.1.3, chapter 3). These issues are tackled by a conceptual model (section 6.3.1, chapter 6) that shows the connection between the key elements of a refurbishment and the indication of a sound theory of production (section 3.2.2.3, chapter 3) along with a set of managerial practices associated to this theory (section 3.2.2.6, chapter 3). This is a novel approach since previous studies have neither been concerned on devising conceptual artefacts to support production management nor focused on discussing which theoretical background could be used as a reference basis for managing and improving production in refurbishment projects.

The conceptual model of refurbishment projects is one of the main theoretical contributions of the study. It permeates every output devised in the research, namely, it is embedded in the framework for project characterisation (section 6.3.2, chapter 6), it underpins the framework of managerial solutions (section 5.3.2.3, chapter 5), and it is the starting point for implementing the proposed method (section 6.3.4.1.1, chapter 6). The artefact is grounded on knowledge from the literature (section 3.1, chapter 3) and it is also sustained by evidence from empirical studies (section 4.2.2, chapter 4, and section 5.1, chapter 5). This conceptual model is an original idea that integrates the basic features of refurbishment with the purpose to increase awareness of project participants regarding the nature of the project, hence helping to address one of the root causes of problems identified in the research. While those characteristics had, of course, been discussed before, an integrated view for supporting and effective construction management in refurbishments was missing. Besides, it is argued that the conceptual model provides a common language that facilitates the understanding of the subject for both academics and practitioners.

The framework for project characterisation presented in section 6.3.2 of chapter 6 is another contribution of the study. The solution comprises a set of dimensions that aims at providing a better understanding of the project for helping managers to cope with the management of complexity innate to refurbishments. Also, it plays the role of providing common ground since it serves as the starting point for the discussions and interactions among project participants. The use of the complexity approach to the construction industry is not new, however dimensions for improving the understanding of refurbishment projects have not yet been articulated in a framework.

The framework of managerial solutions for production management in refurbishment projects presented in section 5.3.2.3 of chapter 5 is also a significant contribution of the research. The artefact was built upon knowledge acquired from the literature (chapter 3) and the empirical studies undertaken (section 4.2.2, chapter 4, and section 5.1, chapter 5). It provides guidance on how to select practices for managing construction in refurbishments by showing the connection between managerial solutions and the peculiarities of those projects. Also, it consolidates the TFV theory as the theoretical background upon which the managerial solutions should be underpinned. The TFV theory is a powerful reference basis for production management as it integrates the three major views on production, namely, transformation, flow, and value. This integrated view on production has been successfully applied in the realm of construction management. Findings from the literature indicate that the adoption of managerial methods based on the TFV theory leads to improvements in project performance. Thus, the TFV theory should be applied to refurbishment projects. The indication of this theory is certainly a distinctive advance promoted by this study. In prior research, the importance of a theory of production for promoting efficiency in refurbishment sites has been neglected. Only few researchers have suggested the use of concepts and principles derived from the TFV theory in refurbishment projects (section 3.2.2.5, chapter 3). Moreover, nobody proposed a framework linking those conceptual solutions as countermeasures to address the root causes of typical problems found in refurbishments. Another advance brought by the framework is the clear differentiation between conceptual and practical solutions. The former refers to flow concept-related principles of production management derived from the TFV theory whereas the latter concerns to guidelines for better project management found in the literature, best practices extracted from empirical studies, and tools and techniques in line with the lean theory. It is shown that the various practical solutions can be anchored to principles derived from the TFV theory. These, in turn, should be seen as drivers for achieving improved production performance. While this is not a novel insight per se, as researchers in the field of lean construction have used principles of the TFV theory for driving improvements in construction processes, this perception has not been properly developed or discussed in the refurbishment literature. Usually, practical solutions are recommended without due consideration regarding their theoretical underpinning.

Another contribution is the simplification of recommendations for improving construction management in refurbishment projects. The author has identified in the literature (section 3.1.2.1, chapter 3) a number of guidelines on how to improve performance of refurbishments. These were grouped into six categories by identifying patterns among those suggestions (section 3.1.2.1.3, chapter 3). Besides, the author has linked those groups of guidelines to principles of the TFV theory. Before, those recommendations were not grounded to a sound theoretical foundation nor articulated in a framework tailored to the refurbishment context.

Finally, it is contended that the method proposed in the thesis (section 6.3.4, chapter 6) is also a theoretical contribution of the study. It advances the existing knowledge by conveying the notion, not yet established in the refurbishment domain, that practices used for managing construction must be based on a sound theoretical foundation, i.e. the TFV theory of production. Another contribution provided by the method is the indication it provides on how that theory should be applied in such a particular context, namely, its application should be based on the typical features of refurbishments, which are represented through the conceptual model devised in the thesis (section 6.3.1, chapter 6). The development of the method was based on the knowledge from literature (chapter 3), findings from empirical studies (section 4.2.2, chapter 4, and section 5.1, chapter 5), and also feedback from practitioners. It is argued that its application helps to address the research problem, i.e. the lack of theory-based construction management approach suited to the basic nature of refurbishment projects.

7.3.2 Practical contributions

The contributions reported in this section are based on three sources of evidence, namely, results from the practical test of the method (chapter 5), perception of experienced practitioners obtained during the focus group (chapter 6), and the author's reflection on findings of the research (chapter 7).

The conceptual model devised in the thesis was acknowledged as an accurate representation of refurbishment projects by the practitioners involved in the third empirical study (chapter 5) and also by the attendees of the focus group (chapter 6). The artefact is helpful for making project participants aware of the importance of integrating the three elements shown in the conceptual model in order to achieve an effective construction management. This is undoubtedly one of the main contributions of the artefact as it helps to address one of the root causes of problems identified in refurbishments, namely, the poor understanding regarding the nature of the project. Indeed, during the focus group it was mentioned that the artefact would be useful to reduce waste in design and construction of refurbishments as it could be used to make clients conscious on the nature of those projects (section 6.2.1.1, chapter 6). Another practical contribution of the artefact is as a framework for locating problems and solutions as demonstrated during the third empirical study (section 5.2.2.2, chapter 5). The use of the conceptual model as a reference basis for improvements was also mentioned as a potential benefit during the focus group. It was argued by the participants of the focus group that the artefact could be also used as a framework for underpinning the quality management system used by the company (section 6.2.1.1, chapter 6).

The framework for project characterisation is beneficial for increasing the awareness of project participants on the complexity of the project. It was perceived by the practitioners as a practical way to make everyone involved in the retrofit conscious of project's features. Furthermore, the artefact is opportune for enabling discussions and actions on issues concerning the production management of refurbishment projects as demonstrated in the third empirical study carried out in the research (section 5.2.2.3, chapter 5).

The framework of managerial solutions was not in its final version when the implementation of the method was carried out, however the practices for managing construction identified throughout the research were advised as candidate solutions for improving production performance. The Last Planner System was selected for practical test and produced several benefits such as lead time compression, reduced waste as waiting time was minimised due to less disruptions in the workflow on site, and improved customer satisfaction as the retrofit lead time was significantly reduced. Improvements in project coordination and communication were also noted as a result of the implementation of the Last Planner (section 5.2.3.2, chapter 5).

The implementation of the method leads to the indication of appropriate approaches of production control (section 5.3.1, chapter 5). Previous research (chapter 3) has shown that companies need assistance on how to select practices for managing construction in refurbishments. Yet, problems faced during the implementation of lean in refurbishment projects have implied that a more structured approach is needed. The artefact fills those gaps through a sequence of steps that promotes an effective process for selecting managerial practices to be utilised in the management of construction in refurbishments. Besides, the author argues that the use of the method helps organisations to get started on lean in refurbishment projects. Another practical contribution of the artefact is the systematised approach it provides for addressing the management of construction in refurbishments. As noted by the participants of the focus group (chapter 6), the method is a structured way to manage a refurbishment project that could be helpful to ensure consistency and standardisation in the management of different projects. Yet, it could be used to streamline communication between stakeholders through the formalisation of decisions made throughout the project (section 6.2.1.3, chapter 6).

7.4 Recommendations for future research

The following topics are recommended to be addressed in future studies:

- Further studies are recommended to better understand the preconditions for implementing the proposed method. This would help to define the scope of applicability of the artefact in different refurbishment contexts;
- The refurbishment sector comprises distinct types of projects such as houses, hospitals, offices, and department stores. Presumably, there are different approaches to different projects. Therefore, it is worthwhile to investigate the suitability of the managerial solutions proposed in this thesis across several types of refurbishments as well as assessing the need of adapting lean tools and techniques to address particular refurbishment contexts;
- Also, based on the previous suggestion, the question emerges: is it possible to create taxonomy of refurbishments in order to devise templates for production management tailored to distinct types of projects? Further research is needed in this regard;
- In order to enhance the performance of works on site, additional studies are also recommended to investigate how to reduce uncertainties related to the existing asset through an improved building surveying process; and
- It is worth investigating how the principles associated to the value view of production could be used for enhancing performance of refurbishment projects;
- Additional studies are also suggested to further develop the list of managerial solutions proposed in the thesis;

- Finally, it would be also worth investigating how Building Information Modelling (BIM) could be used for improving production management in refurbishment projects. It would be good to understand the impact that BIM could have on the future of refurbishments.

References

Ankrah, N.A., & Ahadzie, D.K. (2014). Key challenges of managing building adaptation and retrofit projects. *Structural Survey, 32*(5). doi: 10.1108/SS-10-2014-0035

Aikivuori, A. (1996). Periods and demand for private sector housing refurbishment. *Construction Management and Economics, 14*(1), 3-12. doi: 10.1080/01446199600000002

Anumba, C., Marino, B., Gottfried, A., & Egbu, C. (2004). *Health and safety in refurbishment involving demolition and structural instability.* Health & Safety Executive. Research Report 204. Norwich: HSE Books.

Baccarini, D. (1996). The concept of project complexity – a review. *International Journal of Project Management, 14*(4), 201-204. doi: 10.1016/0263-7863(95)00093-3

Baker, C., Smith, L., & Swan, W. (2013). Make no assumptions: The selection of domestic retrofit improvements. In W. Swan & P. Brown (Eds.), *Retrofitting the built environment* (pp. 99-112). West Sussex: John Wiley & Sons, Ltd.

Ballard, G. (1997). Lookahead planning, the missing link to production control. In *5th Annual Conference of the International Group for Lean Construction (IGLC), Gold Coast, Australia*. Retrieved from http://iglc.net/Papers/Details/17

Ballard, H. G. (2000). *The Last Planner System of Production Control*. (Doctoral Thesis). The University of Birmingham, Birmingham, UK. Retrieved from http://leanconstruction.org.uk/media/docs/ballard2000-dissertation.pdf

Ballard, G. (2006). Rethinking project definition in terms of target costing. In *14th Annual Conference of the International Group for Lean Construction (IGLC), Santiago, Chile*. Retrieved from http://iglc.net/Papers/Details/410

Ballard G. (2008). The Lean Project Delivery System: An Update. *Lean Construction Journal*, 1-19, Retrieved from www.leanconstructionjournal.org

Ballard, G., & Howell, G. (2003). An update on Last Planner. In *11th Annual Conference of the International Group for Lean Construction (IGLC), Virginia, USA*. Retrieved from http://iglc.net/Papers/Details/227

Ballard, G., & Howell, G. (2004). Competing construction management paradigms. *Lean Construction Journal*, 1(1), 38-45. Retrieved from https://www.leanconstruction.org/about-us/publications/lean-construction-journal/lcj-back-issues/volume-1-issue-1-october-2004/

Ballard, G., Koskela, L., Howell, G., & Zabelle, T. (2001). Production System Design in construction. In *Proceedings of the 9th Annual Conference of the International Group for Lean Construction, Singapore*. Retrieved from http://iglc.net/Papers/Details/130

Bertelsen, S. (2003a). Complexity – Construction in a new perspective. In *11th Annual Conference of the International Group for Lean Construction, Virginia, USA*. Retrieved from http://iglc.net/Papers/Details/230

Bertelsen, S. (2003b). Construction as a complex system. In *11th Annual Conference of the International Group for Lean Construction, Virginia, USA*. Retrieved from http://iglc.net/Papers/Details/231

Bertelsen, S., & Emmitt, S. (2005). The client as a complex system. In *13th Annual Conference of the International Group for Lean Construction, Sydney, Australia*. Retrieved from http://iglc.net/Papers/Details/351

Bertelsen, S., & Koskela, L. (2003). Avoiding and managing chaos in projects. In *11th Annual Conference of the International Group for Lean Construction, Virginia, USA*. Retrieved from http://iglc.net/Papers/Details/229

Bertelsen, S., & Koskela, L. (2005). Approaches to managing complexity in project production. In *13th Annual Conference of the International Group for Lean Construction*, *Sydney, Australia*. Retrieved from http://iglc.net/Papers/Details/350

Birrell, G. S. (1980). Construction Planning-Beyond the Critical Path. *Journal of the Construction Division,* American Society of Civil Engineers (ASCE)*, 106*(3), 389-407.

Bryde, J.D., & Schulmeister, R. (2012). Applying Lean principles to a building refurbishment project: experiences of key stakeholders. *Construction Management and Economics, 30*(9), 777-794. doi: 10.1080/01446193.2012.700405

Caccavelli, D., & Gugerli, H. (2002). TOBUS – A European diagnosis and decision-making tool for office building upgrading. *Energy and Buildings*, *34*(2), 113-119. doi: 10.1016/S0378-7788(01)00100-1

Camp, R.C. (1989). *Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance*. Milwaukee: ASQC Quality Press.

Chau, K. W., Leung, A. Y. T., Yiu, C. Y., and Wong, S. K. (2003). Estimating the value enhancement effects of refurbishment. *Facilities, 21*(1/2), 13-19. doi: 10.1108/02632770310460504

Constructing Excellence (2007). Contractor recycles 99.6% of demolition waste at large scale hospital refurbishment. Demonstration project. Retrieved from http://demos.constructingexcellence.org.uk/userimages/Image61.pdf

Construction Industry Institute. (2009). *Front End Planning of Renovation and Revamp Projects - Implementation Resource 242-2*. USA: Construction Industry Institute.

Construction Industry Research and Information Association. (1994). *A guide to the management of building refurbishment - Report 133*. London: CIRIA.

Construction Industry Research and Information Association (2004). *Good practice guidance for refurbishing occupied buildings*. London: CIRIA.

Costa, D. B., Formoso, C. T.; Kagioglou, M., & Alarcon, L. F. (2004). Performance measurement systems for benchmarking in the construction industry. In *12th Annual Conference of the International Group for Lean Construction (IGLC)*, *Copenhagen, Denmark*. Retrieved from http://iglc.net/Papers/Details/292

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*, 22(4). doi: 10.1061/(ASCE)0742-597X(2006)22:4(158)

Creswell, J. W. (2014). *Research design – qualitative, quantitative, and mixed methods approaches* (4th ed.). Croydon: SAGE Publications Ltd.

Crichton, C. (1966). *Interdependence and uncertainty. A study of the building industry*. Tavistock Institute. London: Tavistock Publications Ltd..

Crotty, M. (1998). *The foundations of social research – meaning and perspective in the research process*. Australia: SAGE Publications Ltd.

Cuperus, Y., Wamelink, H., & Resodihardjo, G. (2010). Reducing fit-out time in a Netherlands housing project. In *18th Annual Conference of the International Group for Lean Construction*, Haifa, Israel. Retrieved from http://iglc.net/Papers/Details/676

Dalsgaard, P. (2014). Pragmatism and Design Thinking. *International Journal of Design, 8*(1), 143-155. Retrieved from http://www.ijdesign.org/ojs/index.php/IJDesign/article/viewFile/1087/604

Dave, B. (2013). *Developing a construction management system based on lean construction and building information modelling* (Doctoral Thesis). The University of Salford, Salford.

Department for Business, Innovation and Skills. (2010). *Low Carbon Construction. Innovation and Growth Team. Final Report*. Retrieved from https://www.gov.uk/government/publications/low-carbon-construction-innovation-growth-team-final-report

Department for Business, Innovation and Skills. (2011). *Low Carbon Construction. Action Plan. Government response to the Low Carbon Construction Innovation & Growth Team Report*. Retrieved from https://www.gov.uk/government/publications/low-carbon-construction-innovation-growth-team-report-on-low-carbon-construction-government-response

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

Devecchi, A. M. (2010). *Reformar não é construir. A reabilitação de edifícios verticais: novas formas de morar em São Paulo no século XXl.* (Refurbishment is not building. The rehabilitation of high-rise buildings: new housing forms in Sao Paulo in XXI century). (Doctoral Thesis). University of Sao Paulo, Sao Paulo, Brazil. Retrieved from http://www.teses.usp.br/teses/disponiveis/16/16137/tde-15062010-132024/pt-br.php

Dixon, T. & Eames, M. (2013). Scaling up: the challenges of urban retrofit. *Building Research & Information, 41*(5), 499-503. doi: 10.1080/09613218.2013.812432

Domingo, N., Osmani, M., & Price, A. D. F. (2008). Reducing construction waste in healthcare facilities: a project lifecycle approach. In: *24th Annual Conference of Association of Researchers in Construction Management (ARCOM), Cardiff, UK*. Retrieved from http://www.arcom.ac.uk/-docs/proceedings/ar2008-1183-1192_Domingo_Osmani_and_Price.pdf

Domingo, N., Osmani, M., & Price, A. D. F. (2009). Construction waste minimisation in the UK healthcare industry. In: *25th Annual Conference of Association of Researchers in Construction Management (ARCOM), Nottingham, UK*. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/9193/5/Domingo-Construction-waste-2009.pdf

Domingo, N. (2011). *Reducing construction waste in healthcare projects: a project lifecycle approach* (PhD Thesis), Loughborough University, Loughborough. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/9107

Dulung, A. Z. A. (2007). *Computer aided decision support system for the selection of subcontractors in building refurbishment works*. (PhD Thesis), National University of Singapore, Singapore. Retrieved from https://www.scribd.com/document/326919345/Dulungs-PhD-Thesis-New

Eden, C., & Huxham, C. (1996). Action research for management research. *British Journal of Management*, 7(1), 75-86. doi: 10.1111/j.1467-8551.1996.tb00107.x

Egbu, C. O. (1994). *Management education and training for refurbishment work within the construction industry* (Doctoral Thesis). The University of Salford, Salford. Retrieved from http://usir.salford.ac.uk/14743/

Egbu, C. O. (1995) Perceived degree of difficulty of management tasks in construction refurbishment work. *Building Research and Information, 23*(6), 340-344. doi: 10.1080/09613219508727486

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*, *24*(6), 329-338. doi: 10.1080/09613219608727553

Egbu, C. O., Young, B. A., & Torrance, V. B. (1998). Planning and control processes and techniques for refurbishment management. *Construction Management and Economics*, *16*(3), 315-325. doi: 10.1080/014461998372349

European Commission (2010). *Europe 2020 - A European strategy for smart, sustainable and inclusive growth. Communication from the Comission*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

European Commission (2011). *A Roadmap for moving to a competitive low carbon economy in 2050. Communication from the Comission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions*. Retrieved from http://www.cbss.org/wp-content/uploads/2012/12/EU-Low-Carbon-Road-Map-2050.pdf

Fenves, S.J. (1996). The penetration of information technologies into civil and structural engineering design: state-of-the-art and directions toward the future. Kumar, B. & Retik, A. (Eds.) In *Information Representation and Delivery in Civil and Structural Engineering Design*. Edinburgh: Civil Comp Press.

Future Fit (2011). *Installation phase in-depth findings*. Follow-up report. Retrieved from http://www.affinitysutton.com/media/364661/futurefit-quick-links-PDF-4.pdf

Garthwaite, P., & Eckert, C. (2012). Glitches, snags and crises: a study of change in hospital adaptation projects. In *28th Annual Conference of the Association of Researchers in Construction Management (ARCOM),* Edinburgh, UK. Retrieved from http://oro.open.ac.uk/40102/

Gidado, K. I. (1996). Project complexity: The focal point of construction production planning. *Construction Management and Economics, 14*(3), 213-225. doi: 10.1080/014461996373476

Gomes, D., Koskela, L., Biotto, C., Talebi, S., & Pikas, E. (2017). Shared understanding in construction: a conceptual systhesis. In *5th Workshop When Social Sciences meet Lean and BIM. University College Northern Denmark*. Aalborg, Denmark.

Goodier, C., & Gibb, A. (2007). Future opportunities for offsite in the UK. *Construction Management and Economics, 25*(6), 585-595. doi: 10.1080/01446190601071821

Goulding, C. (2002). *Grounded Theory. A practical guide for management, business and marketing researchers*. London: SAGE Publications Ltd.

Gram-Hanssen, K. (2014). Retrofitting owner-occupied housing: remember the people. *Building Research & Information, 42*(4). doi: 10.1080/09613218.2014.911572

Haarr, K.J., & Drevland, F. (2016). A mandated lean construction delivery system in a rehab project – a case study. In *24th Annual Conf. of the International Group for Lean Construction (IGLC)*, *Boston, USA*. Retrieved from http://iglc.net/Papers/Details/1246

Hart, C. W. L. (1995). Mass customization: conceptual underpinnings, opportunities and limits. *International Journal of Service Industry Management*, 6(2), pp.36-45. doi: 10.1108/09564239510084932

Heim, J., & Compton, W.D. (1992). *Manufacturing systems: foundations of world-class practice*. Washington DC: National Academy Press.

Henrich, G. (2009). *Development of a tool for diagnosing production management efficiency on construction sites* (Doctoral Thesis), The University of Salford, Salford.

Henrich, G., Tilley, P., & Koskela, L. (2005). Context of production control in construction. In *13th Annual Conference of the International Group for Lean Construction (IGLC)*, Sydney, Australia. Retrieved from http://iglc.net/Papers/Details/364

Hevner, A., & Chatterjee, S. (2010). *Design Research in Information Systems. Theory and Practice*. United States: Springer US.

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

Ho, P., & Fischer, M. (2009). *An examination of current practices in identifying occupant interactions in renovations projects - Working Paper #121*. Stanford: Center for Integrated Facility Engineering.

Holm, M. G. (2000). Service management in housing refurbishment: a theoretical approach. *Construction Management and Economics, 18*(5), 525-533. doi: 10.1080/014461900407338

Holmström, J., Ketokivi, M., & Hameri, A. (2009). Bridging practice and theory: a design science approach. *Decision Sciences, 40*(1), 65-87.

Höök, M. (2006). Customer value in lean prefabrication of housing considering both construction and manufacturing. In *14th Annual Conference of the International Group for Lean Construction (IGLC)* Santiago, Chile. Retrieved from http://iglc.net/Papers/Details/427

Höök, M., & Stehn, L. (2005). Connecting lean construction to prefabrication complexity in Swedish volume element housing. In *13th Annual Conference of the International Group for Lean Construction*, Sydney, Australia. Retrieved from http://iglc.net/Papers/Details/377

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 *11th Annual Conference of the International Group for Lean Construction*, *Blacksburg, USA*. Retrieved from http://iglc.net/Papers/Details/240

Howard, S.L.; Gibson Jr., G.E.; Whittington, D.A.; & Cui, Q. (2009). *Analysis Supporting Front End Planning for Renovation and Revamp Projects, Part 1 - Research Report 242-11*. USA: Construction Industry Institute.

Howell, G., Laufer, A., & Ballard, G. (1993). Uncertainty and project objectives. *Project Appraisal*, *8*(1), 37-43.

Howell, G., & Ballard, G. (1996). Can project controls do its job? In *4th Annual Conference of the International Group for Lean Construction (IGLC)*, Birmingham, England. Retrieved from http://iglc.net/Papers/Details/6

Howell, G., and Ballard, G. (1999). *Design of Construction Operations. LCI White Paper 04*. Retrieved from http://www.leanconstruction.org

Howell, G., & Koskela, L. (2000). Reforming project management: the role of lean construction. In *8th Annual Conference of the International Group for Lean Construction (IGLC)*, Brighton, England. Retrieved from http://iglc.net/Papers/Details/107

Howell, G., Ballard, G., & Tommelein, I. (2011). Construction Engineering – Reinvigorating the Discipline. *Journal of Construction Management and Economics, 137(10)*, 740-744. doi: 10.1061/(ASCE)CO.1943-7862.0000276

Hyer, N. L., & Brown, K. A. (1999). The discipline of real cells. *Journal of Operations Management*, 17, 557-574. doi: 10.1016/S0272-6963(99)00003-0

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.* Netherlands: OTB Research Institute for Housing, Urban and Mobility Studies.

Jablite (2017). Jablite Dynamic Insulation CPD at Materials 2017. Retrieved from http://www.jablite.co.uk/news/jablite-dynamic-insulation-cpd-materials-2017/

Johnston, R.B. & Brennan, M. (1996). Planning or organizing: the implications of theories of activity for management of operations. *Omega, International Journal of Management Science*, *24*(4), 367-384. doi: 10.1016/0305-0483(96)00016-3

Johnstone, I. M. (2001). Periodic refurbishment and reductions in national cost to sustain dwelling services. *Construction Management and Economics*, *19*(1), 97-108. doi: 10.1080/01446190010003434

Kasanen, E., Lukka, K., & Siitonen, A. (1993). The constructive research approach in management accounting research. *Journal of Management Accounting Research*, 5, 243-264. Retrieved from https://mycourses.aalto.fi/pluginfile.php/183797/mod_resource/content/1/Kasanen%20et%20al%201993.pdf

Kelly, M.J. (2009). Retrofitting the existing UK building stock. *Building Research and Information*, 37(2), 196-200. doi: 10.1080/09613210802645924

Kemmer, S., & Koskela, L. (2012). Developing a lean model for production management of refurbishment projects. In *20th Annual Conference of the International Group for Lean Construction (IGLC)*, San Diego, USA. Retrieved from http://iglc.net/Papers/Details/788

Kemmer, S., Koskela, L., & Nykänen, V. (2013). *Towards a lean model for production management of refurbishment projects*. ApRemodel Project. VTT Technology 94, Espoo, Finland. Retrieved from http://usir.salford.ac.uk/29292/1/T94_%282%29.pdf

Kemmer, S.L., Heineck, L.F.M., & Alves, T.C.L. (2008). Using the line of balance for production system design. In *16th Annual Conference of the International Group for Lean Construction (IGLC)*, Manchester, UK. Retrieved from http://iglc.net/Papers/Details/579

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 *18th Annual Conference of the International Group for Lean Construction (IGLC)*, Haifa, Israel. Retrieved from http://iglc.net/Papers/Details/732

Kemmer, S., Biotto, C., Koskela, L., & Fazenda, P.T. (2016). Implementing Last Planner in the context of social housing retrofit. In *24th Annual Conference of the International Group for Lean Construction (IGLC)*, Boston, USA. Retrieved from http://iglc.net/Papers/Details/1302

Kenley, R., & Seppanen, O. (2010). *Location-Based Management for Construction. Planning, Scheduling and Control*. Oxon: Spon Press.

Kochikar, V.P. & Narendram, T.T. (1994). On using abstract models for analysis of flexible manufacturing systems. International Journal of Production Research, 32(10), 2303-2322.

Kohler, N., & Hassler, U. (2002). The building stock as a research project. *Building Research & Information*, *30*(4), pp. 226-236. doi: 10.1080/09613210110102238

Koskela, L. (1992). *Application of the New Production Philosophy to Construction*. Technical Report 72. Center for Integrated Facility Engineering. Department of Civil Engineering. Stanford University. Retrieved from https://cife.stanford.edu/sites/default/files/TR072.pdf

Koskela, L. (2000). *An exploration towards a production theory and its application to construction* (Doctoral Thesis). Technical Research Centre of Finland, Espoo. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.6.7319&rep=rep1&type=pdf

Koskela, L. (2008). Which kind of science is construction management? In *16th Annual Conference of the International Group for Lean Construction (IGLC)*, *Manchester, UK*. Retrieved from http://iglc.net/Papers/Details/584

Koskela, L. (2015). Where Rhetoric and Lean Meet. In *23rd Annual Conference of the International Group for Lean Construction (IGLC)*, *Perth, Australia*. Retrieved from http://iglc.net/Papers/Details/1239

Koskela, L. & Howell, G. (2001). Reforming project management: the role of planning, execution and controlling. In *9th Annual Conference of the International Group for Lean Construction (IGLC)*, *Singapore, Singapore*. Retrieved from http://iglc.net/Papers/Details/147

Koskela, L. & Howell, G. (2002). The underlying theory of project management is obsolete. In *Proceedings of the Project Management Institute Research Conference*, 293-302. Retrieved from https://www.pmi.org/learning/library/underlying-theory-project-management-obsolete-8971

Koskela, L., Howell, G., Ballard, G., & Tommelein, I. (2002). The foundations of lean construction. In: Best, R., & de Valence, G. (Eds.). *Design and Construction: Building in Value*. Oxford: Butterworth Heinemann.

Koskela, L., Stratton, R., & Koskenvesa, A. (2010). Last planner and critical chain in construction management: comparative analysis. In *18th Annual Conference of the International Group for Lean Construction (IGLC)*, *Haifa, Israel*. Retrieved from http://iglc.net/Papers/Details/680

Koskela, L., Pikas, E., Gomes, D., Biotto, C., Talebi, S., Rahim, N., & Tzortzopoulos, P. (2016). Towards Shared Understanding on Common Ground, Boundary Objects and Other Related Concepts. In *24th Annual Conf. of the International Group for Lean Construction (IGLC)*, *Boston, USA*. Retrieved from http://iglc.net/Papers/Details/1352

Krizek, R.J., Lo, W., & Hadavi, A. (1996). Lessons learned from multiphase reconstruction project. *Journal of Construction Engineering and Management, 122*(1), 44-54.

Ladhad, A., & Parrish, K. (2013). The role of lean practices for zero net energy retrofits. In *21st Annual Conference of the International Group for Lean Construction (IGLC)*, *Fortaleza, Brazil*. Retrieved from http://iglc.net/Papers/Details/921

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*, *52*(5), 438-445. doi: 10.1002/ajim.20678

Laufer, A. (1991). Construction planning in uncertain environments. *International Journal of Project Management, 9*(1), 53-60. doi: 10.1016/0263-7863(91)90057-3

Laufer, A., Denker, G.R., & Shenhar, A.J. (1996). Simultaneous management: the key to excellence in capital projects. *International Journal of Project Management, 14*(4), 189-199. doi: 10.1016/0263-7863(95)00091-7

Lee, H. (2012). Renovation scheduling to minimize user impact of a building that remains in operation. *Automation in Construction*, 22, 398-405. doi: 10.1016/j.autcon.2011.09.018

Lehtonen, J. L., & Kiiras, J. M. (2010). Cost modelling in underpinning projects. *Construction Management and Economics*, *28*(9), 985-995. doi: 10.1080/01446193.2010.487537

Li, M., & Yang, J. (2014). Critical factors for waste management in office building retrofit projects in Australia. *Resources, Conservation and Recycling*, 93, 85-98. doi: 10.1016/j.resconrec.2014.10.007

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

Lillrank, P. (1995). The transfer of management innovations from Japan. *Organization Studies, 16*(6), 971-989. doi: 10.1177/017084069501600603

Liu, F. (2015). *Integrated change and knowledge management for energy efficient retrofit projects* (Doctoral Thesis). The Pennsylvania State University, US. Retrieved from https://etda.libraries.psu.edu/catalog/27215

Lu, W., Olofsson, T., & Stehn, L. (2011). A lean-agile model of homebuilders' production systems. *Construction Management and Economics*, *29*(1), 25-35. doi: 10.1080/01446193.2010.531027

Lukka, K. (2000). The key issues of applying the constructive approach to field research. In Reponen, T. (ed.) *Management Expertise for the New Millennium*. *Publications of the Turku School of Economics and Business Administration, A-1:2000*, 113-128.

Lukka, K. (2003). The constructive research approach. In Ojala, L. & Hilmola, O. (Eds.), *Case study research in logistics*. Turku, Finland: Turku School of Economics and Business Administration.

Lundberg, M., & Lidelöw, H. (2016). Testing a proposition for a knowledge management method for refurbishment. In: 32nd *Annual Conference of the Association of Researchers in Construction Management (ARCOM) Manchester, UK*. Retrieved from http://ltu.diva-portal.org/smash/get/diva2:1000710/FULLTEXT01.pdf

Mansfield, J. (2009). Sustainable refurbishment: policy direction and support in the UK. *Structural Survey*, 27(2). doi: 10.1108/02630800910956470

Mansfield, J. (2011). Sustainable refurbishment: some practical regulatory hurdles. *Structural Survey*, *29*(2). doi: 10.1108/02630801111132803

March, S.T., & Smith, G.F. (1995). Design and natural science research on information technology. *Decision Support Systems*,*15*(4), 251-266. doi 10.1016/0167-9236(94)00041-2

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 *19th Annual Conference of the International Group for Lean Construction (IGLC)*, *Lima, Peru.* Retrieved from http://iglc.net/Papers/Details/1111

Maturana, S., Alarcon, L.F., & Deprez, M. (2003). Modelling the impact of multiskilling and concrete batch size in multi-storey buildings. In *11th Annual Conference of the International Group for Lean Construction (IGLC)*, *Virgina, USA*. Retrieved from http://iglc.net/Papers/Details/259

McKim, R., Hegazy, T., & Attalla, M. (2000). Project performance control in reconstruction projects. *Journal of Construction Engineering and Management, 126*(2), 137-141. doi: 10.1061/(ASCE)0733-9364(2000)126:2(137)

Melles, B., & Wamelink, J.W.F. (1993). *Production control in construction* (Dissertation). Retrieved from http://repository.tudelft.nl/view/ir/uuid%3A76a252fa-a12c-4919-8bc9-7d7baa07cd51/

Mertens, D. (2005). *Research and evaluation in education and psychology. Integrating diversity with quantitative, qualitative, and mixed methods* (2nd ed.). Thousand Oaks: Sage Publications Ltd.

Miller, E., and Buys, L. (2008). Retrofitting commercial office buildings for sustainability: tenants' perspectives. *Journal of Property Investment & Finance*, 6(6). doi: 10.1108/14635780810908398

Mitropoulos, P., and Howell, G.A. (2002). Renovation projects: design process problems and improvements mechanisms. *Journal of Management in Engineering*, 18(4), 179-185. doi: 10.1061/(ASCE)0742-597X(2002)18:4(179)

Naaranoja, M., & Uden, L. (2007). Major problems in renovation projects in Finland. *Building and Environment*, *42*(2), 852-859. doi: 10.1016/j.buildenv.2005.10.001

National Building Specification. (2015). What is a U-value? Heat loss, thermal mass and online calculators explained. Retrieved from https://www.thenbs.com/knowledge/what-is-a-u-value-heat-loss-thermal-mass-and-online-calculators-explained

New Civil Engineer (2013). Cure for a sickly hospital. (2013, 31 January). *New Civil Engineer*, 20-23.

Noori, A., Saruwono, M., Adnan, H., and Rahmat, I. (2016). Conflict, complexity, and uncertainty in building refurbishment projects. In *International Civil and Infrastructure Engineering Conference*, Singapore, Singapore.

Okoroh, M. I., & Torrance, V. B. (1999). A model for subcontractor selection in refurbishment projects. *Construction Management and Economics*, *17*, 315-327. doi: 10.1080/014461999371529

Office for National Statistics (2014). *Output in the Construction Industry. Table 10 – Value of construction output in Great Britain*. Retrieved from http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Output+in+the+Construction+Industry#tab-data-tables

Peer, S. (1974). Network analysis and construction planning. *Journal of Construction Division,* American Society of Civil Engineers (ASCE), *100*(3), 203-210.

Pereira, D., & Cachadinha, N. (2011). Lean construction in rehabilitation works – suitability analysis and contribution for the definition of an application model. In *19th Annual Conference of the International Group for Lean Construction*, Lima, Peru. Retrieved from http://iglc.net/Papers/Details/1136

Quah, L. K. (1992). Comparative variability in tender bids for refurbishment and new build work. *Construction Management and Economics*, *10*(3), 263-269. doi: 10.1080/01446199200000022

Rahmat, I.B. (1997). *The planning and control process of refurbishment projects* (PhD Thesis). University College London, London. Retrieved from http://discovery.ucl.ac.uk/1317640/1/265000.pdf

Ramirez, R. R., Alarcon, L. F., & Knights, P. (2004). Benchmarking system for evaluating management practices in the construction industry. *Journal of Management in Engineering*, *20*(3). doi: 10.1061/(ASCE)0742-597X(2004)20:3(110)

Ravetz, J. (2008). State of the stock – What do we know about existing buildings and their future prospects? *Energy Policy*, *36*(12), 4462 – 4470. doi: 10.1016/j.enpol.2008.09.026

Rocha, C. G. (2011). *A conceptual framework for defining customisation strategies in the house-building sector*. (Doctoral Thesis), Federal University of Rio Grande do Sul, Porto Alegre. Retrieved from http://www.lume.ufrgs.br/handle/10183/38795

Rocha, C. G., Kemmer, S. L., Meneses, L., & Formoso, C. T. (2013). Managing the information flow in customised apartment building projects. In *21th Annual Conference of the International Group for Lean Construction (IGLC), Fortaleza, Brazil*. Retrieved from http://iglc.net/Papers/Details/942

Rooke, C.N. (2012). *Improving wayfinding in old and complex hospital environments* (PhD Thesis), University of Salford, UK. Retrieved from http://usir.salford.ac.uk/27358/1/Thesis.pdf

Ross, B., Hansen, D., Lieske, T., Krude, J., Saner, F., Marggraf, G., Paul, A., Jakob, H. G., Popp, W. (2011). Refurbishment works in a hospital during normal operation. *GMS Krankenhaushygiene Interdisziplinär*, 6(1), 1-7. doi: 10.3205/dgkh000168

Rother, M., & Harris, R. (2001). *Creating continuous flow. An action guide for managers, engineers and production associates. A Lean Toolkit Method and Workbook*. The Lean Enterprise Institute. Massachusetts: Brookline.

Roy, R., Low, M., Waller, J. (2005). Documentation, standardization and improvement of the construction process in house building. *Construction Management and Economics*, *23*(1), 57-67. doi: 10.1080/0144619042000287787

Sacks, R., & Goldin, M. (2007). Lean management model for construction of high-rise apartment building. *Journal of Construction Engineering and Management*, *133*(5), 374-384. doi: 10.1061/(ASCE)0733-9364(2007)133:5(374)

Sacks, R., Treckmann, M., & Rozenfeld, O. (2009). Visualization of work flow to support lean construction. *Journal of Construction Engineering and Management*, *135*(12), 1307-1315. doi: 10.1061/%28ASCE%29CO.1943-7862.0000102

Santos A., Moser, L., & Tookey, J.E. (2002). Applying the concept of mobile cells manufacturing on the drywall process. In *10th Annual Conference of the International Group for Lean Construction (IGLC)*, Gramado, Brazil. Retrieved from http://iglc.net/Papers/Details/207

Sanvido, V. E., & Riggs, L. S. (1991). *Managing retrofit projects - Technical Report No. 25*. USA: Construction Industry Institute.

Sapountzis, S. (2013). *An investigation into the development of an effective benefits realisation process for healthcare infrastructure projects* (Doctoral Thesis), The University of Salford, Salford. Retrieved from http://usir.salford.ac.uk/29293/

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students* (5th ed.). Essex: Pearson Education Limited.

Saurin, T. A., Rooke, J., & Koskela, L. (2013). A complex systems theory perspective of lean production. *International Journal of Production Researc*h, 51(19), 5824-5838. doi:10.1080/00207543.2013.796420

Saurin, T.A., Rooke, J., Koskela, L., & Kemmer, S. (2013). Guidelines for the management of complex socio-technical systems: an exploratory study of a refurbishment project. In *21st Annual Conference of the International Group for Lean Construction (IGLC), Fortaleza, Brazil*. Retrieved from http://iglc.net/Papers/Details/945

Schramm, F. K., Costa, D. B., & Formoso, C. T. (2004). The design of productions systems for low-income housing projects. In *12th Annual Conference of the International Group for Lean Construction (IGLC), Elsinore, Denmark*. Retrieved from http://iglc.net/Papers/Details/299

Schramm, F., Rodrigues, A., & Formoso, C.T. (2006). The role of production system design in the management of complex projects. In *14th Annual Conference of the International Group for Lean Construction (IGLC)*, Santiago, Chile. Retrieved from http://iglc.net/Papers/Details/447

Seppänen, O., & Aalto, E. (2005). A case study of line-of-balance based schedule planning and control system. In *13th Annual Conference of the International Group for Lean Construction (IGLC)*, Sydney, Australia. Retrieved from http://iglc.net/Papers/Details/373

Shafer, S. M., & Rogers, D. F. (1991). A goal programming approach to the cell formation problem. *Journal of Operations Management, 10*(1), 28-44. doi: 10.1016/0272-6963(91)90034-U

Shenhar, A.J., & Laufer, A. (1995). Integrating product and project management – a new synergistic approach. *Engineering Management Journal*, 7(3), 11-15. doi: 10.1080/10429247.1995.11414847

Sheth, A. Z., Price, A. D. F., Glass, J., & Achour, N. (2008). Reviewing the sustainability of existing healthcare facilities. In: *24th Annual Conference* of the Association of Researchers in Construction Management (*ARCOM), Cardiff, UK*. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/6580/1/REVIEWING_THE_SUSTAINABILITY_OF_EXISTING_HEALTHCARE_FACILITIES%5B1%5D.pdf

Sheth, A. Z., Price, A. D. F., & Glass, J. (2010a). A framework for refurbishment of healthcare facilities. In: *International Conference of the* Health and Care Infrastructure Research and Innovation Centre (*HaCIRIC), Edinburgh, UK*. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/6651/1/Smeth%201.pdf

Sheth, A. Z., Price, A. D. F., & Glass, J. (2010b). BIM and refurbishment of existing healthcare facilities. In *26th Annual Conference* of the Association of Researchers in Construction Management (*ARCOM)*, *Leeds, UK*. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/6653/1/Sheth%202.pdf

Sheth, A. Z., Price, A. D. F., & Glass, J. (2010c). Existing healthcare facilities, refurbishment, and energy simulation. In: *International Conference on the Constructed Environment, Venice, Italy*. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/8289/1/C1.pdf

Sheth, A. Z. (2011). *A refurbishment framework with an emphasis on energy consumption of existing healthcare facilities* (PhD Thesis), Loughborough University, Loughborough. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/9077

Shingo, S. (1988). *Non-stock production: The Shingo System for Continuous Improvement*. Cambridge: Productivity Press, Inc.

Singh, Y.P. (2007). *A framework for production management of renovation projects*. (MSc Thesis). Michigan State University, Michigan.

Slack, N., Chambers, S., Harland, C., Harrison, A., & Johnston, R. (1997). *Operations Management*. Atlas: Sao Paulo.

Smart, P.R., Mott, D., Sycara, K., Braines, D., Strub, M. and Shadbolt, N.R. (2009). Shared Understanding within Military Coalitions: A Definition and Review of Research Challenges. In Knowledge Systems for Coalition Operations, Southampton, UK. Retrieved from https://eprints.soton.ac.uk/267173/2/KSCO2009_-_Shared_Understanding.pdf

Soini, M., Leskelä, I., & Seppänen, O. (2004). Implementation of line-of-balance based scheduling and project control system in a large construction company. In *12th Annual Conference of the International Group for Lean Construction (IGLC)*, *Elsinore, Denmark*. Retrieved from http://iglc.net/Papers/Details/313

Souza, D. V. S. (2015). *A conceptual framework and best practices for designing and improving construction supply chains* (Doctoral Thesis). The University of Salford, Salford. Retrieved from http://usir.salford.ac.uk/34437/

Swan, W. (2013). Retrofit innovation in the UK social housing sector: A social-technical perspective. In: Swan, W., & Brown, P. (Eds.). (2013). *Retrofitting the built environment* (pp. 36-52). West Sussex: John Wiley & Sons, Ltd.

Swan, W., & Brown, P. (Eds.). (2013). *Retrofitting the built environment*. West Sussex: John Wiley & Sons, Ltd.

Swan, W., Ruddock, L., Smith, L., & Fitton, R. (2013). Adoption of sustainable retrofit in UK social housing. *Structural Survey*, *31*(3), 181-193. doi: 10.1108/SS-12-2012-0039

Technology Strategy Board (2013). *Retrofit Revealed. The Retrofit for the Future projects – data analysis report. March T13/28*. Swindon: Technology Strategy Board. Retrieved from https://www.innovateuk.org/documents/1524978/2138994/Retrofit+Revealed+--+The+Retrofit+for+the+Future+projects+-+data+analysis+report/280c0c45-57cc-4e75-b020-98052304f002

Technology Strategy Board (2014). *Retrofit for the future. Reducing energy use in existing homes. A guide to making retrofit work. April T14/026*. Swindon: Technology Strategy Board. Retrieved from https://www.innovateuk.org/documents/1524978/2138994/Retrofit%20for%20the%20future%20-%20A%20guide%20to%20making%20retrofit%20work%20-%202014

Tezel, B.A. (2011). Visual management: an exploration of the concept and its implementation in construction. (PhD Thesis). The University of Salford, Salford. Retrieved from http://usir.salford.ac.uk/26941/

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 *19th Annual Conference of the International Group for Lean Construction (IGLC)*, Lima, Peru. Retrieved from http://iglc.net/Papers/Details/1103

Tsao, C.C.Y. (2005). *Use of work structuring to increase performance of project-based production systems* (PhD Thesis). University of California, Berkeley, US. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.68.5581&rep=rep1&type=pdf

Tsao, C.C.Y., Tommelein, I.D., Swanlund, E.S., & Howell, G.A. (2004). Work structuring to achieve integrated product-process design. *Journal of Construction Engineering and Management, 130*(6), 780-789. doi: 10.1061/(ASCE)0733-9364(2004)130:6(780)

Tuholski, S.J., & Tommelein, I.D. (2008). Design Structure Matrix (DSM) implementation on a seismic retrofit. In *16th Annual Conference of the International Group for Lean Construction (IGLC), Manchester, UK*. Retrieved from http://iglc.net/Papers/Details/615

Tuholski, S.J., Gursel, A.P., Tommelein, I.D., & Bomba, G. (2009). Lean comparison using process charts of complex seismic retrofit projects. *Journal of Construction Engineering and Management*, 135(4), 330-339. doi: 10.1061/(ASCE)0733-9364(2009)135:4(330)

Vaishnavi, V. K., & Kuechler, W. Jr. (2007). *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. Boca Raton, FL: Taylor & Francis Group.

van Aken, J. E. (2004). Management research based on the paradigm of the design sciences: the quest for field-tested and grounded technological rules. *Journal of Management Studies*, 41(2), 219-246. doi: 10.1111/j.1467-6486.2004.00430.x

van Aken, J. E., Berends, H., & van der Bij, H. (2007). *Problem solving in organizations. A methodological handbook for business students*. New Delhi: Cambridge University Press.

Voordijk, H. (2009). Construction management and economics: the epistemology of a multidisciplinary design science. *Construction Management and Economics*, 27(8), 713-720. doi: 10.1080/01446190903117777

Vrijhoef, R. (2016). Effects of Lean Work Organization and Industrialization on Workflow and Productive Time in Housing Renovation Projects. In *24th Annual Conf. of the International Group for Lean Construction (IGLC), Boston, USA*. Retrieved from http://iglc.net/Papers/Details/1283

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*, *135(*10), 999-1008. doi: 10.1061/(ASCE)CO.1943-7862.0000072

Wilkinson, S. J. (2012). Guest editorial. Special Issue: Building Adaptation and Sustainability. *Structural Survey*, *30*(3). doi: 10.1108/ss.2012.11030caa.001

Willey, A. (2013). FutureFit: Lessons for the Green Deal from a retrofit large-scale project in UK social housing. In: W. Swan & P. Brown (Eds.). *Retrofitting the built environment* (pp. 128-140). West Sussex: John Wiley & Sons, Ltd.

Whiteman, W.E., & Irwig, H.G. (1988). Disturbance scheduling technique for managing renovation work. *Journal of Construction Engineering and Management, 114*(2), 191-213. doi: 10.1061/(ASCE)0733-9364(1988)114:2(191)

Whittington, D.A., Gibson Jr., G.E., and Cui, Q. (2009). *Analysis supporting Front End Planning for Renovation and Revamp Projects - Part 2. Research Report 242-12*. USA: Construction Industry Institute.

Williams, T. M. (1999). The need for new paradigms for complex projects. *International Journal of Project Management*, *17*(5), 269-273. doi: 10.1016/S0263-7863(98)00047-7

Williams, T. (2002). *Modelling complex projects*. West Sussex: John Wiley & Sons, Ltd.

Worley, D. J., & Hohler, S. E. (2008). OR Construction Project: from planning to execution. *AORN Journal*, 88(6), pp. 917-941.

Yamin, R.A., & Harmelink, D.J. (2001). Comparison of linear scheduling model (LSM) and Critical Path Method (CPM). *Journal of Construction Engineering and Management, 127*(5), 374-381. doi: 10.1061/(ASCE)0733-9364(2001)127%3A5(374)

Yin, R. K. (2003). *Case study research. Design and methods* (3rd Ed.). Thousand Oaks: Sage Publications Ltd.

Appendix 1 - Categories of guidelines

A number of guidelines for managing refurbishment projects were found through the literature review. The author identified patterns among those recommendations and grouped them into six categories:

- Foster collaboration, engagement, and early involvement
- Safeguard users and operations in the existing building
- Reduce uncertainty
- Use appropriate contract strategies, procurement routes, and management systems
- Provide contingencies
- Work with skilled people in refurbishment projects

In this appendix, the full list of guidelines found in the literature is presented according to the categories mentioned above.

Foster collaboration, engagement, and early involvement

<u>General guidelines</u>

- Promote close collaboration between the parties, i.e., client, contractors, designers, building managers, etc., and identify decision makers and their areas of responsibility (CIRIA, 1994);
- Select the project team early (Egbu, 1997; Mitropoulos and Howell, 2002). Encourage early involvement of the construction team with the design (CIRIA, 1994);
- Make sure that all project participants are aware of project objectives (CIRIA, 1994);
- Plans of work and work schedules must be realistic and must be seen to be so by those who have to work to them (CIRIA, 1994).

<u>Refurbishment of time-dominated projects</u>

- Extensive communication of the plan and progress against the plan, perhaps even hour to hour, both within the refurbishment team and to affected users (CIRIA, 1994, p.31).

<u>Refurbishment of occupied buildings</u>

- Project planning
    - In order to conduct a proper briefing talk to all parties likely to be affected by the refurbishment (CIRIA, 2004, p. 23).
- Time and programming
    - Involve builders as early as possible to avoid problems later (CIRIA, 2004, p. 34);
    - Marked-up building plans may be easier to understand than complex programme charts (CIRIA, 2004, p. 41).

- Project team
    - The project team should collaborate and understand each other’s roles and responsibilities, within an appropriate procurement route (CIRIA, 2004, p. 42);
- Communication
    - Develop a communication plan describing who is responsible for communicating with which stakeholders, and what resources will underpin this work (CIRIA, 2004, p. 54);
    - Try to make sure that all stakeholders have the information they need, without releasing contentious material (CIRIA, 2004, p. 54);
    - Put effort into involving the construction workforce in the project (CIRIA, 2004, p. 59);
    - Get all the people working on the refurbishment project into a shared office (CIRIA, 2004, p. 60).
- Health and safety
    - Health and safety management should be integrated with all other aspects of the project (CIRIA, 2004, p. 63);
    - Involve all parties in formulating the health and safety plan – and follow it (CIRIA, 2004, p. 68).

<u>Refurbishment involving demolition and structural instability</u>

- Clients need to be more involved in the health and safety management of the refurbishment projects they are procuring (Anumba et al., 2004, p.9);
- Communication of project information and the client’s health and safety requirements has to be considered a priority issue for the development of effective health and safety management strategies (Anumba et al., 2004, p.10);
- New communication systems such as drawing-based method statements or the use of pictures or video for health and safety training is strongly recommended for supporting health and safety education of foreign language workers (Anumba et al., 2004, p.10).

<u>Refurbishment of hospitals</u>

- Operating rooms renovation projects require planning and collaboration among physicians, hospital staff members, and vendors in order to ensure that all needs are met and any issues or concerns are addressed before construction begins (Worley and Hohler, 2008, pp. 917-919);
- Communication between team members can be facilitated throughout the planning, design, and building phases at regularly scheduled meetings. Communication tools can

include minutes, a newsletter, updated memos, and bulletin boards designated for construction issues (Worley and Hohler, 2008, p. 939);

- A multidisciplinary team should be established. It should perform risk assessment and determine necessary protective measures before starting any construction, renovation or maintenance work in health care settings (Ross et al., 2011, p. 1);
- Communication and cooperation between experts connected to the renovation and users of the building is necessary to succeed in the project (Lahtinen et al., 2009, p. 444).

<u>Retrofits</u>

- Project planning
  - Researching the market for products and suppliers early on (TSB, 2013, p.25);
  - Performance targets help unite project teams (TSB, 2014, p.8);
  - An initial meeting at the home helps design teams understand existing conditions, the overall strategy and the installation process (TSB, 2014, p.8);
  - Early engagement of residents helps in understanding their needs and managing their expectations (TSB, 2014, p.8);
  - Early talks with suppliers can ensure that products and services are chosen according to the suppliers' capabilities (TSB, 2014, p.8);
  - Early engagement with local planners reduces the risk that proposed solutions may not be approved (TSB, 2014, p.8).
- Site management
  - Dedicated co-ordination of the retrofit project (TSB, 2013, p.25);
  - Engaging and motivating the project team early on (TSB, 2013, p.25);
  - Open and frequent communication between project team members (TSB, 2013, p.25);
  - Understanding among the site staff of the importance of achieving good air-tightness (TSB, 2013, p.25);
  - Continued involvement of the design team once on site (TSB, 2014, p. 34);
  - Briefings to help teams to understand and commit to the retrofit aims (TSB, 2014, p. 34);
  - Site operatives should watch airtightness tests to see the results of their work (TSB, 2014, p. 34);
  - Whichever supply chain model is chosen, clear responsibilities and communication are critical (TSB, 2014, p. 34).
- Understanding the supply chain
  - Building relationships with manufacturers (TSB, 2013, p. 25);

  - Working with the suppliers of control systems to ensure that those installed are fit-for-purpose and simple to understand (TSB, 2013, p. 25).

- Working closely with residents

  - Engaging residents early and frequently in the process (TSB, 2013, p. 25);
  - Helping residents to understand how to manage their homes at different times of the year by explaining system controls (TSB, 2013, p. 25);
  - Continual engagement with residents during the project (TSB, 2014, p. 40);
  - Tours of the house while work is under way (TSB, 2014, p. 40).

- Retrofit in general

  - Work packages need to be tailored for each property to take into account the property attributes, condition, and resident needs (FutureFit, 2011, p. 3);
  - The potential to bring retrofit costs down needs to be assessed by engaging with the supply chain and integrating work packages more closely with maintenance regime and overall asset management programme (FutureFit, 2011, p. 3);
  - The role of the resident liaison officers (RLOs) was key in explaining the project and its implications. They needed to be on hand during the works to resolve any issues and maintain resident engagement in the scheme (Willey, 2013, p. 134);
  - The delivery teams felt that resident engagement needed to go beyond getting a 'yes' to the works; residents needed to fully understand the installation process and the implications of adapting packages of works (Willey, 2013, p. 134);
  - For these works to have their desired impact and to ensure a smooth process, FutureFit findings suggest that the entire delivery team – including contractors, surveyors, and RLOs – need training. This will make sure that the same message and levels of understanding are passed on to residents (Willey, 2013, p. 136).

Safeguard users and operations in the existing building

<u>General guidelines</u>

- Provide assistance to users in managing disruptions (CIRIA, 1994);
- Integrate the operational facility's schedule of the existing facility into the construction schedule (McKim et al., 2000).

<u>Refurbishment of occupied buildings</u>

- Project planning

  - The client should appoint a planning supervisor for health and safety issues and should also consider appointing an expert on risk and value management (CIRIA, 2004, p. 20).

- Time and programming
    - The programme for refurbishment should be coordinated with occupants' activities. Effective time management can reduce conflicts between occupants and builders (CIRIA, 2004, p. 33).
- Communication
    - Make every effort to ensure that people who are affected by the refurbishment know what is happening, and allow them to say what they think (CIRIA, 2004, p. 56).
- Health and safety
    - Keep building occupants (and the public) away from any potential hazards (CIRIA, 2004, p. 64);
    - Occupants, builders, and members of the public must have clear routes out of the building in case of emergency (CIRIA, 2004, p.73).
- Circulation and site boundary
    - The project team need to plan access before starting work on site. They should map out emergency access routes, routes for vehicles, and contractor routes inside the building (CIRIA, 2004, p. 77);
    - Set aside an external area for the contractor's use, to avoid conflict with the occupants (CIRIA, 2004, p. 80);
    - Establish physical boundaries between the internal areas for the builders and occupants (CIRIA, 2004, p. 81);
    - Minimise inconvenience to occupants (CIRIA, 2004, p. 84);
    - Ensure the builder has freedom to deliver materials in the most efficient manner to minimise disruption (CIRIA, 2004, p. 86).
- Security
    - Separate the occupied and builders' areas and avoid insecure access routes between them, and ensure that the builder's site area has a secure boundary (CIRIA, 2004, p. 91);
    - Establish an access control system to ensure that only authorised people can get into the builder's working area (CIRIA, 2004, p. 92);
    - Ensure that construction workers wear identifiable clothing (CIRIA, 2004, p. 93);
    - Avoid creating temporary access routes during refurbishment (CIRIA, 2004, p. 96).
- Noise, dust and other pollution
    - Eliminate or reduce the creation of noise, dust and other pollution (CIRIA, 2004, p. 97);

- Create the noise, dust and other pollution at times when it does not affect business continuity (time separation) (CIRIA, 2004, p. 97);
- Ensure that occupants and business operations are well insulated from the noise, dust and pollution (physical separation) (CIRIA, 2004, p. 97);
- Select building methods that create less noise, dust and pollution (CIRIA, 2004, p. 100).

Refurbishment involving demolition and structural instability

- There is the need for a key figure in charge of the coordination of all structural information elaborated during the design phase and of the supervision of the design of temporary works and of the planning of demolition activities (Anumba et al., 2009, p.9).

Refurbishment of hospitals

- The plan should include patient safety, as well as patient, physician, and staff flow. It must include infection control, safety guidelines, potential risk management issues, and adherence to all regulatory agency guidelines (Worley and Hohler, 2008, p. 923);
- Renovation projects require also a plan for completing demolition and construction without disrupting the daily functions of the operating room. This demolition plan may need to be broken into phases to maximize productivity. Demolition and construction of a centrally located area may require off-hours work to minimise noise and distraction to all involved. In addition, interim life safety measures must be in place and staff members educated on the guidelines for safety and infection control for the construction project (Worley and Hohler, 2008, p. 923);
- A preconstruction risk assessment should be conducted after barrier walls are up to protect the working areas of the operating room (Worley and Hohler, 2008, p. 938);
- Daily inspections and meetings between the project director and contractor provide valuable oversight of the construction. Additionally, daily documentation must show that high-efficiency particulate air machines are running constantly and filters have been changed as required (Worley and Hohler, 2008, p. 938);
- During demolition, carry out daily checks to ensure that trash is being removed in covered bins, that the area is clean, that there are no water leaks, and that wet blankets or stick mats are strategically placed to contain dirt and dust (Worley and Hohler, 2008, p. 938);
- Throughout the construction process, daily inspections by infection control staff members, environmental engineers, and the project director or other designated personnel occur and are documented (Worley and Hohler, 2008, p. 938);
- Teams should include in the plans all areas that construction will affect, especially the areas adjoining the construction zone (Worley and Hohler, 2008, p. 938);

- As the construction project is completed, a checklist can ensure that everything is completed and in working order (Worley and Hohler, 2008, p. 941);
- In terms of protective measures, dust-protecting walls were installed insulating the ward from the affected construction areas. Also, negative pressure was maintained in affected rooms during building activity and exhaust air was conducted outside through a sealed hole in the window (Ross et al., 2011, p. 2);
- Patients with increased risk of invasive aspergillosis should be identified and should be moved to other wards far away from construction and renovation areas and use of mobile HEPA (high-efficiency particulate air) filters should be considered (Ross et al., 2011, p. 6);
- Air pressure gradients are advised to be regularly verified in artificially ventilated areas (Ross et al., 2011, p. 6).
- Noise, dust, and vibration must be kept to an absolute minimum due to potential adverse effects on patient recovery time (CE, 2007, p. 1);
- Construction must take place without disrupting patients' recovery and new and innovative solutions have to be sought (CE, 2007, p. 2).

<u>Retrofits</u>

- Project planning
  - Temporary services can be installed for people who stay at home during the works (TSB, 2014, p. 8);
  - Items made off site (e.g. modular heating pods, pre-fabricated roofs) can be easier to install on site (TSB, 2014, p. 8).
- Working closely with residents
  - Decanting residents (TSB, 2013, p. 25);
  - Training support staff (call centre, maintenance) to provide informed, ongoing help to residents (TSB, 2013, p. 25).
  - If there are delays or additional works, give residents time to reflect and adapt to them (TSB, 2014, p. 40);
  - A handover should cover all elements of the retrofit, but with particular attention to the different systems and how use them together as one system (TSB, 2014, p. 40);
  - Provide user-friendly controls and clear guidance (TSB, 2014, p. 40);
  - Aftercare visits to make sure people are comfortable and are using systems well (TSB, 2014, p. 40);
  - Visit again when new residents move in (TSB, 2014, p. 40).

- Retrofit in general
    - Although none of the technical issues are insurmountable, consideration needs to be given to aligning the work programme to trigger points to keep both costs and disruption to a minimum. Certain property types are intrinsically less suited to specific measures and in this case due consideration should be given to the cost-benefit of alternative options/specifications (FutureFit, 2011, p. 3).

Reduce uncertainty

General guidelines

- Conduct extensive investigation work on the existing building (CIRIA, 1994);
- Improve the quality and timing of relevant information for the works (Egbu et al. 1998);
- Accelerate the discovery of the existing conditions and constraints (Mitropoulos and Howell, 2002);
- Reduce and if possible eliminate uncertainty in the programme with the purpose to meet project objectives (CIRIA, 1994);
- Determine the procedures for information flows among the parties involved in the project to make clear the consequences of changes among project participants (CIRIA, 1994);
- Increase the percentage level of design completion before commencement of the works (Egbu et al., 1998);
- Contractors must be fully informed of the constraints under which they will have to work (Krizek et al., 1996);
- Assist clients in the decision making process by providing the cost implications of each design option on a timely manner, including any consequent repercussion in the normal operations of the building and users (CIRIA, 1994);
- Use rapid prototyping (Mitropoulos and Howell, 2002).

Refurbishment of time-dominated projects

- Exhaustive preparation (CIRIA, 1994, p. 31).

Refurbishment of occupied buildings

- Health and safety
    - Carry out surveys to identify the presence of materials that may be hazardous (CIRIA, 2004, p. 71).

Refurbishment involving demolition and structural instability

- Prior to undertaking any demolition activity on site that may interfere with the structural stability of the building, preliminary surveys and site investigations have to be carried out by structural engineers as well as specialist demolition contractors (Anumba et al., 2004, p. 9).

Retrofits

- Project planning
  - Time spent in detailed pre-design (TSB, 2013, p. 25);
  - Retrofit must be tailored to specific, existing conditions of the house (TSB, 2014, p. 8);
  - Detailed surveys, flexibility and contingency plans are all needed (TSB, 2014, p.8).
- Understanding the supply chain
  - Anticipating the availability, price, and lead time of innovative products (TSB, 2013, p. 25).

Use appropriate contract strategies, procurement routes, and management systems

General guidelines

- Assess alternative contract strategies for the procurement of design and construction work against project objectives, constraints and risks (CIRIA, 1994; Egbu, 1997);
- Set up a management system and contractual procedures compatible with project objectives. Make sure they are sufficiently flexible to be able to cope with changes (CIRIA, 1994; Egbu, 1997).

Refurbishment of time-dominated projects

- Organising to allow fast reactive management responses, for example by delegating authority for decisions, including commitment of contingency monies and by having sophisticated communication systems (CIRIA, 1994, p. 31).

Refurbishment of occupied buildings

- Project planning
  - The client should choose a procurement route compatible with their objectives for the refurbishment and the nature of the project (CIRIA, 2004, p. 21);
  - The form of contract is critical in establishing cooperation and avoiding confrontation (CIRIA, 2004, p. 31).

- Time and programming
  - Establish a practical and efficient project programme (CIRIA, 2004, p. 34).
- Project team
  - The project team should collaborate and understand each other's roles and responsibilities, within an appropriate procurement route (CIRIA, 2004, p. 42);
  - Select procurement routes and forms of contract that reinforce cooperation not confrontation, and involve the builder as early as possible (CIRIA, 2004, p. 47).

<u>Retrofits</u>

- Working on site
  - Effective and informed project management and coordination (TSB, 2014, p. 34);
  - A realistic timetable with a logical sequence of works, well-structured contracts and clear expectations on the supply chain can mitigate delays (TSB, 2014, p. 34).

Provide contingencies

<u>General guidelines</u>

- Provide contingencies in programmes and estimates to deal with unforeseen situations and users of the building (CIRIA, 1994);
- Allow time and money in the plan for extensive consultation with users, neighbours, planning authorities, etc. (CIRIA, 1994).

<u>Refurbishment of time-dominated projects</u>

- Realistic contingencies in plans, programme and resources, including options and fall-back positions (CIRIA, 1994, p. 31);
- Organising to allow fast reactive management responses, for example by delegating authority for decisions, including commitment of contingency monies and by having sophisticated communication systems (CIRIA, 1994, p. 31);
- Having an ultimate, but confidential, fall back of an operational contingency plan if the time window is exceeded (CIRIA, 1994, p. 31).

<u>Refurbishment of occupied buildings</u>

- Project team
  - Develop "what if?" scenarios in advance (CIRIA, 2004, p. 49).

Refurbishment of hospitals

- Multiple solutions (e.g. fall back plans) have to be pre-planned to cope with the uncertainty inherent to refurbishment projects (NCE, 2013, p. 22).

Retrofits

- Project planning
    - Detailed and realistic project planning, including extensive contingency planning and risk management (TSB, 2013, p. 25);
    - Detailed surveys, flexibility and contingency plans are all needed (TSB, 2014, p. 8).

Work with skilled people in refurbishment projects

General guidelines

- Work with experienced people who have a good track record on refurbishment projects, e.g., a specialist contractor (CIRIA, 1994; Krizek et al., 1996).

Refurbishment of occupied buildings

- Project planning
    - Make sure that the firms and individuals have the capability to deliver (CIRIA, 2004, p. 46).

Refurbishment involving demolition and structural instability

- Refurbishment projects involving demolition activities require the appointment of competent and qualified professionals who are going to implement health and safety in the development of any stage of the project, from design to execution phase (Anumba et al., 2004, p.9).

Appendix 2 – Interview protocol

Questions used in the semi-structured interviews conducted with project participants during the empirical studies carried out throughout the research:

- What are the main characteristics of refurbishment projects that make them different from new build projects?
- What are the typical problems / issues encountered in the production phase of refurbishment projects? Do you know what the root causes of these problems are?
- What are the current managerial methods adopted by the company for managing production in refurbishment projects?
- What kind of wastes exists in the production management of refurbishment projects? How representative are they? Which are the root causes of these wastes?
- What is the pattern of production processes in refurbishment projects?
- What are the influential factors affecting planning and control effectiveness?
- Could you provide examples of areas to improve on?