THESIS FOR THE DEGREE OF DOCTOR OF TECHNOLOGY

Construction Performance Measurement

Site Managers in Refurbishment Projects

AHMET ANIL SEZER

Department of Technology Management and Economics
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2016

Construction performance measurement: Site managers in refurbishment projects
AHMET ANIL SEZER
ISBN: 978-91-7597-486-6

Doktorsavhandlingar vid Chalmers tekniska högskola.
Ny serie Nr 4167
ISSN 0346-718X

Division of Service Management and Logistics
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Göteborg, Sweden

Printed by Chalmers Reproservice
Göteborg, Sweden 2016

Abstract

Firms use management accounting, controls and performance measurement to ensure that employee activities are aligned with organizational goals and strategies. Performance is measured at different levels: industry, firm, project and activity. While productivity is a commonly used measure of performance at the industry level, in the construction industry, sustainability is more often used at the firm and project levels. Monitoring resource use in refurbishment projects is desirable from a sustainability and productivity viewpoint. Also, in the context of criticisms levelled at the construction industry for being a major generator of waste, demolition activities in refurbishment are important. The purpose of this thesis is to investigate how construction performance is measured by focusing on refurbishment site managers' monitoring and management of resource use.

An initial analysis of the relations between construction industry productivity and measures of construction project performance indicates that what might appear to suggest low levels of productivity growth in official statistics can be explained in part by the limited range of output and input qualities considered. Current measures of productivity in refurbishment projects are limited to simple, area-based key indicators. To obtain a better measure of productivity requires the range of output and input qualities to be extended using data captured from performance measures typically used for projects.

This thesis draws on the data collected in three empirical studies. The first empirical study is based on 8 short, semi-structured interviews. The data in second empirical study was collected through 27 semi-structured interviews. Data collection in the third empirical study involved a pilot questionnaire survey, short semi-structured interviews and, finally, a national questionnaire designed to collect information from refurbishment site managers. To minimize bias related to medium choice, the national questionnaire was distributed by both e-mail and by post in paper format.

Resource use monitoring and management at refurbishment sites includes site managers' monitoring of resource use and their waste management practices. The literature indicates that site managers' waste management efforts are influenced by several factors, which may be project related, organizational and personal, technical, or related to the industry culture and legislation. The data here show that waste sorting is the only common waste management activity conducted on refurbishment sites. Project size, level of contract detail and specific client demands for waste management are the three main factors associated with waste management efforts. Large projects may benefit from fewer problems related to site space and availability of more extensive services from waste contractors, including advice during project planning. Although the statistical analysis shows that the relation between contract type

(traditional/design-build) and waste practices is weak, there is a potential for reducing waste generation by integrating the project design and the detailed planning of refurbishment activities on site. In this context, more efficient information and communication technologies (ICT) for developing and using digital building information models are desirable.

Findings indicate that ICT support for managing resource use on refurbishment sites can be understood mainly as being a case of technology acceptance. Refurbishment site managers' ICT choices are influenced more by performance expectancy than by effort expectancy. Laptops and traditional pen and paper are the most frequently used media by refurbishment site managers, although they often use tablets in private. Screen size, ease of data entry and information updating are important. Respondents saw little need to link to clients' ICT systems.

Flexible organizational policies related to environmental sustainability allow managers in project-based firms to respond to projects with different characteristics and limitations and to clients with different requirements and standards. Therefore it is worth to study the dilemma of routinizing employees' actions in environments requiring flexibility for making decisions such as in large, project-based organizations that deliver business services.

Keywords: *performance, resource use, waste management, monitoring, productivity, sustainability, ICT, refurbishment, construction industry*

Acknowledgements

I could not complete this thesis without the support of a number of people whom I would like to thank. Jan Bröchner, as my main supervisor, you did not only give me the opportunity to do a PhD, but also you were a great support and adviser. I would like to thank you for inspiring me and being patient, and all the footnotes including origins of words. I would like to thank the co-supervisors: Henrik Eriksson, thank you so much for being available whenever I needed your support and all the interesting perspectives you brought from your healthcare services knowledge; Holger Wallbaum, I am grateful that I had the opportunity to enjoy your international experiences of sustainable building research, thank you for your suggestions and advices on building this thesis.

Special thanks to Pernilla Gluch who provided me with fruitful feedback at my licentiate seminar and Henrik Linderoth at University of Jönköping for constructive comments at my final seminar. I would like to thank the reference group members for the CMB project: Christina Claeson-Jonsson, Pär Åhman, Göran Nilsson, Stefan Marshall and Anders Söderman for sharing their knowledge of the construction industry. I want to also thank Ida Gremyr and Nina Edh here at Chalmers University of Technology, Keith Hampson at the Sustainable Built Environment National Research Centre (SBEnrc), Karen Manley at Queensland University of Technology, Carl Haas at the University of Waterloo, Susanne Balslev Nielsen at the Technical University of Denmark and Faïz Gallouj at Lille 1 University for their valuable feedback at key seminars and informal discussions. I would like to thank Hendry Raharjo for statistical advice and Cynthia Little for language check.

I owe a lot to my dear colleagues at the Division of Service Management and Logistics. I did not only learn how to be a good researcher, but also learnt a lot about life, Swedish culture and history and to look at things from different perspectives. I also got the opportunity to taste various delicious foods from different parts of the world. I am thankful to the department's administration and special thanks go to Alexandra Ericsson, Yvonne Olausson, Madeleine Akbas and Annika Hederström.

This PhD project has been funded by The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) under contract No. 2010-980, Chalmers University of Technology Centre for Management of the Built Environment (CMB), the Swedish Construction Confederation (BI), the National Transdisciplinary Centre of Excellence for Integrated Sustainable Renovation (SIRen) project and ProcSIBE (Procurement for Sustainable Innovation in the Built Environment). I appreciate the database information provided by the Sverige Bygger AB.

I am deeply grateful to all the interviewees and questionnaire respondents for their contribution to my research.

Last but not least, I would like to express my sincere gratitude to my family and friends for helping me to question and find the way, and for their love and support.

Göteborg, October 2016

Ahmet Anıl Sezer

LIST OF APPENDED PAPERS

Paper I – The construction productivity debate and the measurement of service qualities

Sezer, A.A. and Bröchner, J. (2014), *Construction Management and Economics*, 32(6), pp. 565-574. An earlier version was presented at the RESER 2011 conference - Productivity of Services NextGen-Beyond Output/Input, Hamburg, 8-9 September 2011.

Authored jointly by Sezer and Bröchner. While Sezer mainly focused on the literature related to the construction industry, Bröchner made the comparison with the EU KLEMS database and brought in the service literature. The analysis and conclusion was a joint effort.

Paper II – Contractor use of productivity and sustainability indicators for building refurbishment

Sezer, A.A. (2015), *Built Environment Project and Asset Management*, 5(2), pp. 141-153.

Single authored by Sezer.

Paper III – Factors influencing building refurbishment site managers' waste management efforts

Sezer, A.A., submitted to a scientific journal. An earlier version was presented at the CIB Joint International Symposium Going North for Sustainability, London, 23-25 November 2015.

Single authored by Sezer.

Paper IV – ICT use for monitoring resource use on building refurbishment sites

Sezer, A.A. and Bröchner, J., submitted to a scientific journal. An earlier version was presented at the RESER 2015 conference - Innovative Services in the 21st Century, Copenhagen, 10-12 September 2015.

Authored jointly by Sezer and Bröchner. Empirical data collected by Sezer and analysis written jointly by Sezer and Bröchner.

Table of Contents

1 Introduction

Performance is measured at various levels including industry, firm, activity and, in project-based industries, project level. At the industry level, productivity is one of the most frequent measures of performance. Productivity has been defined as “a ratio of volume measure of output to a volume measure of input use” (OECD, 2001, p.11). This definition of productivity is based on the market prices of outputs and inputs. The construction industry suffers from low rates of productivity growth and explaining declining productivity growth has entertained scholars for many decades (Allen, 1985; Dacy, 1965; Stokes, 1981; Ruddock and Ruddock, 2011; Abdel-Wahab and Vogl, 2011). Productivity measurement in the construction industry is difficult due to problems, which apply also to the services sector, related to measuring quality changes (Griliches, 1992). In services, it can be difficult to define output, to distinguish it from input and, therefore, to measure it (Djellal and Gallouj, 2013). These problems apply also to refurbishment since, compared to other construction activities, its service characteristics are more obvious (Holm, 2000). In order to measure productivity more accurately, the range of input and output quality indicators needs to be extended to include not only goods related indicators but also service related indicators such as customer satisfaction and data on client productivity. This does not imply that productivity measures in construction projects are complicated, but rather that data should be captured from performance measures related to projects.

New methods for measuring firm level performance are being developed and introduced almost continuously. At the firm level, performance measurement belongs to management accounting. The term management accounting is often used interchangeably with management control systems (MCS) although, according to Chenhall (2003), management accounting is limited to the collection of practices that includes budgeting and product costing, while MCS cover both management accounting systems and other controls such as personal controls. Malmi and Brown (2008) refer to five types of MCS: cultural, planning, cybernetic, reward and compensation, and administrative. Management accounting practices fall into the category of cybernetic controls, which typically include budgets, financial measures, non-financial measures and hybrids of these components.

Performance measurement is one of the main goals of cybernetic controls. MCS are criticized for being incapable of supporting sustainable development in all its three aspects and mainly being developed for environmental sustainability. In a recent study, nevertheless, cybernetic controls are found to be widely used for sustainable development at the organizational level, especially a sub-type of cybernetic controls, namely corporate performance management (Lueg and Radlach, 2016). Guenther et al. (2016) make an attempt to integrate MCS with environmental sustainability in order to manage and control that corporate environmental strategies are implemented.

Environmental MCS include environmental management accounting and unlike traditional management accounting systems, environmental management accounting includes activities of identification, collection, estimation, analysis, internal reporting as well as use of physical flow information on materials and environmental cost information (e.g. energy consumption, waste disposal).

In this thesis, the narrower management accounting concept is more relevant; I exclude management control based on employees' beliefs and the firm culture. This choice of focus does not imply that environmental sustainability issues are not influenced by the corporate culture.

Since the early 1990s, firm level performance measurement has not been limited only to financial performance; new Information and Communication Technologies (ICT), especially spreadsheet software, is facilitating data collection and data storage. New performance dimensions, including environmental performance and quality performance, have been introduced. With support of ICT, alternative approaches for capturing project performance data arose, including automatic data collection with sensors, using crowdsourcing and collecting data through a common database where data can be entered by several users and establishing a database for benchmarking.

Project performance is measured for many reasons such as benchmarking, rewarding and monitoring whether the firm's strategy is working well at all levels of the organization. Project performance metrics are used for ex post evaluation and are designed as relative measures comparing planned and actual performance. Performance can be monitored in ongoing projects by benchmarking with typical industry figures during different project phases (Yun et al., 2016). Traditionally, the main performance aspects of construction projects are cost, schedule and quality performance. Criteria for project managers' performance might refer to how project managers perform as individuals (Dainty et al., 2003), however, in this thesis, the emphasis is on refurbishment project processes.

Sustainability has become a widely applied performance measure in major construction firms. The concept of sustainability currently is considered to be three-dimensional and involving environmental, economic and social aspects. The effect of refurbishment on social sustainability is often associated with urban renewal of low income areas where the effects are observed after the refurbishment is completed. Energy savings in the post refurbishment phase obviously are interesting in the context of environmental sustainability, but contractor energy use during the refurbishment process does not influence environmental sustainability significantly. Hence, most building certification schemes do not include energy use during the refurbishment process in their energy assessment, but focus on potential energy improvements in the refurbished building (Kamaruzzaman et al., 2016).

Efficient use of resources can improve productivity performance and by reducing waste generation and other negative environmental effects can improve environmental performance. Resources include both economic and biological resources, human and natural resources and tangible and intangible resources. Resource use can be monitored to improve performance until the marginal gains from resource use monitoring are equal to its marginal costs. It is not easy to measure labour skills and ecological qualities of material resources, and to price them. In a market economy, the prices of materials and natural resources do not reflect the depletion and environmental costs in full (Andersen, 2007). Negative externalities related to the use of environmental resources can be internalized using taxes and dumping fees, but this is not always feasible.

How refurbishment is defined determines which processes are covered. There is no consensus among practitioners and researchers on how refurbishment should be defined and there are many terms that are used as synonyms for refurbishment including the words maintenance, repair, replacement, rehabilitation, restoration. In this thesis the term refurbishment is preferred. Mansfield (2002) criticizes definitions of refurbishment for being too vague and not setting limits to the different processes involved in refurbishment, or being too narrow and limiting the reader's perspectives. In this thesis, refurbishment is understood as the Swedish “ombyggnad” which refers to modernization and improvement of a building combined with maintenance, alterations and updates, but not extensions. The main processes involved in refurbishment projects are design, procurement, refurbishment, followed by the post-refurbishment phase. The focus here is on the refurbishment process.

Refurbishment is characterized by demolition and unforeseen conditions. Measuring performance as deviations in refurbishment projects is more complicated since unforeseen conditions making it difficult to develop precise plans to compare later with the outcomes. Fiedler (1987) identifies several restrictions to the scheduling of building modernization projects including minimizing disruptions to building use, the spatial and temporal concentration of modernization tasks, discontinuous resource allocation and uncertainty related to the duration of several activities. Compared to new construction, the services nature of refurbishment, as already mentioned, is strong, and the uncertainties pertaining to the existing building, and the involvement of tenants, are distinguishing aspects. Unlike most types of manufacturing, refurbishment is difficult to standardize and ways to improve productivity based on manufacturing assembly lines are difficult to apply. Use of prefabricated building components is the closest refurbishment comes to being a standardized activity. Complexities and uncertainties in refurbishment arise from incomplete designs, types of procurement, number of subcontractors, availability of materials and skilled labour, limited site space and problems related to accessing sites (Rahmat, 1997). In addition, there can be

greater dependence on subcontractors in refurbishment and clients often appear to be more involved in refurbishment projects compared to new construction.

The client perspective is typical of early studies of refurbishment projects such as energy efficiency refurbishment where clients face financial barriers and are actively engaged in the procurement and follow-up stages (Olsson et al., 2015). Clients are knowledgeable about their houses and their renovation needs, which makes client demand and client involvement important (Malmgren, 2014). On the other hand, with the exception of a few studies (see e.g. Egbu, 1997; McKim et al., 2000), the contractor perspective in the refurbishment process is mostly ignored.

Site managers' practices on refurbishment sites vary because refurbishment organizations are decentralized. Decentralization allows refurbishment site managers flexibility and room for quick responses (Egbu, 1999). The influence of site managers over the success or failure of construction projects in general is strong (Polesie, 2012). They have been described as “the king[s] of construction sites” (Gluch and Räisänen, 2012) and project leaders responsible for the day-to-day management of the construction site (Styhre, 2008). The day-to-day parts of the work, mainly production related duties, are now often transferred to foremen with site managers mostly engaged in planning, procurement, documentation and reporting, and project management (Styhre, 2006). The administrative activities vary based on head office requirements and force site managers to prioritize among different tasks (Styhre and Josephson, 2006). In the construction industry, site managers are referred to also as production managers. There is a distinction between site managers and project managers; site managers spend most of their working hours on the construction site while project managers are more often engaged in desk based administrative duties related to more than one project. Refurbishment site managers can be compared to Information Technology (IT) project managers, given that the majority of IT services involve refurbishing existing IT bases. Also, IT projects are decentralized and IT project managers tend to work at customers’ sites, much like refurbishment site managers.

Monitoring and management of resources are time demanding activities which can be facilitated by use of ICT. Previous studies provide evidence of links between site managers’ IT use and project performance. For new construction, Ling and Tan (2015) find a relation between site managers’ IT use for updates and project monitoring and better time performance, higher quality and client satisfaction. Similar performance improvements could be achieved in refurbishment projects where the refurbishment site manager uses IT for updates and project monitoring.

1.1 Purpose and research questions

The purpose of this thesis is to investigate how construction performance is measured by focusing on refurbishment site managers' monitoring and management of resource use. It investigates three research questions:

RQ1. Which are the relations between construction industry productivity and measures of construction project performance?

The construction industry suffers from low productivity growth rates. This first research question requires investigation of the causes of low productivity growth rates in the construction industry and how measures of construction project performance could contribute to better measurement of productivity.

RQ2. How is resource use monitored and managed by refurbishment site managers?

At the project level, productivity and sustainability performance are important. Although encompassed by the concept of productivity, resource use and waste management often are linked to environmental and economic sustainability. This second research question requires investigation of the measures used to monitor resource use and how resource use is managed, by focusing on monitoring by refurbishment site managers. Here, resource use management refers particularly, but not only, to waste management.

RQ3. How is resource use monitoring and management supported by ICT tools on refurbishment sites?

Due to the number of production related and administrative duties, site managers are required to prioritize among these activities on refurbishment sites. Lack of time is often cited by site managers, although this might refer only to that certain activities are not prioritized. Use of advanced ICT should increase the efficiency of monitoring and managing resources. However, before advanced ICT support is introduced, it is necessary to have an overview of how ICT is used by refurbishment site managers. The third research question therefore addresses use of ICT for resource use monitoring and management by refurbishment site managers.

As for the second and third research questions, this study is limited to refurbishment of multifamily housing and office buildings in Sweden. It is intended to contribute to the scientific fields of construction management and services.

1.2 Outline of the thesis

The thesis consists of an extended summary and four appended papers. Chapter 2 presents the theoretical framework of the thesis; Chapter 3 describes the research methods, data collection and analysis and discusses limitations of this research.

Chapter 4 summarizes the appended papers which are discussed in Chapter 5. Chapter 6 concludes with a number of implications for practice and suggestions for future research.

2 Theoretical framework

As already indicated, performance measures are applied at different levels: industry, firm, project and activity. Productivity is an important industry level measure while concepts such as efficiency are applied typically at the firm level. In projects, especially construction projects, sustainability measures related to environmental, economic and social sustainability are applied increasingly. Resource use including waste management are the input component of the productivity formula and also influence primarily environmental, and economic sustainability. As already mentioned, this study focuses on site managers during the refurbishment process; what the client pays is mostly determined in advance, which is why output measurement is not considered here.

2.1 Performance measurement systems

In this thesis, the focus is on construction performance measurement, in particular site managers' monitoring and management of resource use. According to Malmi and Brown (2008), performance measurement is an important part of cybernetic control, which includes the activities of measuring performance, comparing performance to standards and providing feedback about unwanted variances. Typical cybernetic control components are budgets, financial measures, non-financial measures and hybrids such as balanced scorecard. Thus, cybernetic control systems include management accounting systems.

Management accounting theories explain the form, use and change of accounting systems across a range of conditions (Malmi and Granlund, 2009). These conditions can include company size (Davila, 2005). Although decentralized, organizations which rely heavily on suppliers and contractors are expected to have more aggregate accounting practices and performance measurement systems as well as more centralized contracting (Feltham et al., 2015). Clearly, there are links between the structure of the organization (centralized or decentralized), the size of the organization and the performance measurement system.

Firms measure their performance for obvious reasons including the rewards tied to performance measures, and benchmarking to check the firm's progress against that of competitors in order to develop and evaluate new strategies (Eccles, 1991). Firms expand the number of their performance measures and, according to McAdam and Bailie (2002), traditional financial measures are not sufficient because performance measures need to be aligned to the business strategy, which is affected by the changing nature of the work, increasing competition, specific improvement initiatives, national and international quality awards, changing organizational roles, changing external demands and the power of IT. Bititci et al. (2012) add global sustainability and question how performance measurement systems can incorporate sustainability

dimensions in order to integrate sustainability measures. For service firms, both the type (public or private) and size (large or small) of the organization affect performance measurement and also its service characteristics, namely the role of customer contact and customization (Jääskeläinen and Laihonen, 2014). Clearly, advances in ICT, especially spreadsheet software, are allowing easier data collection and storage, which are enabling the introduction of new dimensions of performance such as environmental and quality performance.

At the project level, cost, schedule and quality have been the traditional main performance measurement areas in construction projects and, based on these measures only, new construction projects have been shown to perform better than refurbishment projects (McKim et al., 2000). This can be explained by the difficulties associated with refurbishment projects including unforeseen site conditions, lack of information about the existing building, limited space for construction, health and safety of current occupants, and involvement of more parties including occupants. In particular, related to quality, complaints from occupants about dust, noise and smoke nuisance are substantially higher in many refurbishment projects.

2.2 Productivity performance in the construction industry

Productivity is an important performance measure at the industry level based on its relation to economic growth. According to official statistics in many countries, the construction industry is associated with low productivity growth rates. Most explanations of low productivity growth in the construction industry do not go beyond the short term. Dacy (1965) highlights shifts in construction product mix, geographical distribution (different design and building codes in different US states), increased construction firm size in contract construction, introduction of new techniques, decline in average age of construction workers, and increased capital per worker. Low productivity growth in the construction industry can probably be explained by: (i) lack of a clear definition of the industry and its boundaries, and (ii) mismeasurement of productivity. Developing reliable and robust industry productivity measures has been discussed in many previous studies; without such measures, the state of construction productivity will remain an unanswered question (Dadi et al., 2014).

Previous studies of construction contractors in Sweden indicate that when site managers use the term “productivity” they often are referring to cost (Forsberg, 2008; Polesie, 2011). In this thesis, productivity is understood according to the OECD definition already mentioned as “a ratio of volume measure of output to a volume measure of input use”, which is based on the market prices for outputs and inputs. In construction projects, partial productivity measures, which are used by firms and construction management researchers, often include labour productivity, machine productivity and materials consumption. As also mentioned earlier, the service nature

of refurbishment is strong (Holm, 2000). Therefore, relying only on physical units, such as cubic metres of concrete layed, as outputs, is not appropriate. Also, the difficulties involved in determining inputs, due to their varying quality, such as in the case of labour, are evident.

Input in the productivity formula, refers to resources and by using resources efficiently, productivity performance can be improved as well as environmental performance by reducing negative environmental effects. Resource use can be monitored to improve productivity, but it is not straightforward to measure labour skills or the ecological qualities of material resources and, subsequently, to price them. Therefore, it is interesting to investigate actual resource use monitoring practices on refurbishment sites.

2.3 Environmental sustainability in the construction industry

Sustainability is included in the annual reports of most major construction firms and sustainability performance measures are becoming widely applied. Use of building certification schemes is one way of measuring sustainability in construction projects. Building certification schemes are not just marketing tools, but involve objective evaluation of performance to provide design guidelines, encourage dialogue between project actors, and drive the market towards higher sustainability (Cole, 2005). In refurbishment projects, evaluation criteria in these schemes go beyond typical environmental sustainability measures, such as energy, sustainable sites, materials, water and waste, and include innovation, economic, social and cultural measures (Kamaruzzaman et al., 2016).

Sustainability is understood as referring to more than the environmental dimension. In refurbishment projects, sustainability is seen as including energy savings, increased comfort, healthier working environments, extended building life cycle, economical exploitation and environmental protection (Mickaityte et al., 2008). In studies analysing sustainability in refurbishment projects from a contractor perspective, social sustainability is seldom the focus given that the effects of refurbishment on social sustainability are mainly associated with the post refurbishment context. However, workers' occupational health and safety and occupants' comfort are social sustainability issues which are raised by the refurbishment process.

Energy use is a major aspect of environmental sustainability. In energy efficiency refurbishment (retrofit) projects, the aim is to reduce the energy use of a building in the post refurbishment phase, while the energy used by the contractor during the refurbishment process is comparatively less important for environmental sustainability. Research on energy efficiency refurbishment is associated mostly with the interests of refurbishment clients (property owners) and, particularly, their efforts

during the procurement and follow-up stages, and the financial barriers they face (Olsson et al., 2015) or relating to how energy retrofitting increase rents and social inequities (Mangold et al., 2016).

Environmental sustainability can be analysed from two perspectives: conservationist (anthropocentric) and preservationist (biocentric). Passmore (1980, p. 73) distinguishes these: “the conserver of forests has his eye on the fact that posterity, too, will need timber, the preserver hopes to keep large areas of forest forever untouched by human hands”. Applying conservationist and preservationist views to the refurbishment process raises significant issues. Resource use and waste management are important elements of the research questions addressed in this thesis, and both activities require use of natural resources by and for humans, in line with the conservationist view. From the preservationist perspective, refurbishment and, especially, energy retrofit projects, are useful since these activities aim to reduce resource use and the negative impacts on nature. Thus the conservationist view is essentially short term when it refers to the refurbishment process while the preservationist view corresponds to the post-refurbishment situation.

2.4 Resource use and waste management

Excessive use of resources and bad management of resources have negative impacts not only on environmental sustainability at the local and global levels but also on productivity. Measures of resource use and waste management are typical sustainability measures, which often are linked to environmental and economic sustainability. Hill and Bowen (1997) acknowledge reduced materials use, maximized reuse and recycling of resources, and use of renewable resources in their list of sustainable construction principles. Shen et al. (2007) classify labour, materials and waste disposal costs under economic sustainability, while waste generation, resource consumption, materials reuse, waste classification, special waste treatment and waste recycling and reuse are classified under environmental sustainability. In the present study, the focus is on monitoring labour, construction materials and waste management services.

A special case of monitoring resource use is waste management and, in the construction industry, waste management activities include reducing waste generation, sorting, reusing, recycling and disposal. Inefficient use of resources contributes to waste generation; the construction industry is ranked first in European Union statistics for waste production and second in Sweden after mining and quarrying (Eurostat, 2016). Waste is produced by demolition, which is frequent in refurbishment projects; it is produced also from poor materials handling practices, design changes and inaccurate documents (Fadiya et al., 2014). Waste generation in refurbishment can be reduced depending on how the waste is generated.

Factors influencing refurbishment site managers' waste management efforts can be categorized as project related factors, organizational and personal factors, technical factors, industry culture and legislation. Project related factors are last minute client requirement changes, incomplete or inaccurate contract documents (Li and Yang, 2014), uncertain project nature (Li, 2012), contract type (Withana-Gamage, 2011), architects avoiding waste generation (Osmani et al., 2008) and clients being focused on financial returns rather than environmental issues (Udawatta et al., 2015). Organizational and personal factors include company size (Begum et al., 2009), attitude of site management (Yu et al., 2013), seeing waste as inevitable, lack of managerial commitment, resources and incentives (Teo and Loosemore, 2001), site staff knowledge of waste management methods and issues, and support from top management (Lingard et al., 2000). Technical factors include limited site space (Li, 2012) and lack of facilities (Teo and Loosemore, 2001). The other factors are legislation, waste practices considered to be impractical, costly, obstructing normal work, causing delays, disposal fees being insignificant (Poon et al., 2013), and industry culture in general (Ajayi et al., 2016). In this thesis, the effects of the industry culture are reflected in lack of incentives for subcontractors, organizational policy and support and contract type.

Having demonstrated the role of resource use and waste management, it is necessary to explore how monitoring and management of these activities can be facilitated. There is obvious potential to improve resource use monitoring and waste management performance through the use of ICT which can vary from very simple versions like pen and paper to advanced ICT tools.

2.5 Tools for monitoring and management: ICT use

Today, ICT is applied in the construction industry to support operations, to communicate and share (documents, drawings) and to store information for reuse. A recent longitudinal study of IT use in the Swedish building sector notes rapid increase in general use of IT (Samuelson and Björk, 2014). The results of their study indicate that all fixed workplaces had computers and Internet access already in 2007. Temporary workplaces, such as construction sites, took advantage of mobile connectivity including Internet access alternatives. Swedish contractors are using IT increasingly for materials management and purchasing although there is less use of electronic document management and Building Information Modelling (BIM). Swedish contractors generally present a lower IT maturity than architects and technical consultants. IT maturity and the perceptions of managers influence acceptance of new technologies in decentralized organizations such as medium and large construction contractors.

Use of technology in organizations can be mandatory or voluntary. According to one influential theory, media choice is based on media richness and media are used to reduce uncertainty and resolve equivocality (Daft and Lengel, 1986). Media richness theory explains why organizations offer certain types of media to their employees, mainly to manage information, organizational learning and knowledge sharing. Organizational learning and knowledge sharing practices in the construction industry require social capital and rely on direct communication rather than formal reporting systems and intranets (Styhre, 2008). This thesis does not investigate why organizations offer certain types of media or the role of organizational learning in the acceptance of ICT; instead it focuses on why individuals choose different media since the choice on construction sites appears not to be dictated completely by the organization.

In organizations with decentralized structures, managers' media choice is voluntary to some extent and is influenced heavily by individual acceptance. The Technology Acceptance Model (TAM) is the pioneering model explaining the diffusion of IT by individuals. In the original TAM model, Davis (1989) defines behavioural intention to use a technology as the decisive factor with perceived usefulness and perceived ease of use as two other factors influencing behavioural intention to use. It is worth noting that, when applying the TAM model in mandated environments, the primary and secondary determinants of behavioural intention are ease of use and perceived usefulness (Brown et al., 2002). The UTAUT (Unified Theory of Acceptance and Use of Technology) synthesis model (Venkatesh et al., 2003) has been adopted by many researchers and includes four constructs: performance expectancy, effort expectancy, social influence and facilitation conditions. While performance expectancy in the UTAUT model is similar to the perceived usefulness of the TAM model, effort expectancy is similar to the perceived ease of use. In this thesis the TAM and the UTAUT models are used in the following ways: ease of use related measures include ease of data entry, ease of updating project information, ease of linking to BIM models and accessibility; usefulness measures include links to client's system and mobile availability. Relevant UTAUT moderators, namely age, experience and voluntariness of use, are included in the present investigation.

Using IT diffusion models for the construction industry requires acknowledgement of the industry characteristics. Construction projects are often short term, temporary and require different groups of construction professionals to work together. Adriaanse et al. (2010) note time pressure as a restriction when introducing new ICT in construction projects. Several actors are involved in construction projects and one of the parties might mandate interorganizational ICT use, for instance, by requesting digital documentation. However, contractual requirements related to the use of certain technologies can face resistance from site managers. Several studies which apply the TAM model to the construction industry, show that usefulness is a stronger

determinant than ease of use, and also include social influence, job relevance, top management support (Son et al., 2012) and the technical features of mobile devices including screen size, input methods such as touch-screen or voice recognition, storage capability, mobility and durability (Chen and Kamara, 2008) as determinants of IT use. Advanced ICT, such as BIM, on construction sites is said to be hindered by lack of mobile devices and employees familiar with use of BIM (Mäki and Kerosuo, 2015). It is suggested that implementation of BIM requires not only tools but also changes to site managers' daily tasks such as collaboration with designers and encouraging them to participate in design management processes.

Job relevance, including daily routines, tasks and ICT support for daily tasks, is important for ICT use, which makes it similarly important to understand construction site managers' daily routines, tasks and information needs. Tenah (1986) refers to primary functions and information needs of construction staff already in the mid-1980s. He considers construction site managers' primary functions to be supervising and organizing the work of foremen, and supervising equipment, materials and services to ensure that project is built within schedule, overseeing budget, safety and quality standards, directing all pre-construction activities and directing inspection and completing punch lists, warranties and operating data. In order to carry out these tasks, site managers require : (i) blueprints, specifications and other contract documents; (ii) local union and labour activities, safety regulations, labour agreements, quality control and testing regulations; (iii) work status and progress reports, detailed schedule, critical item action reports and a field diary; and (iv) purchase order control, shop drawing and sample control, procurement status, field labour, back charges, vendor and subcontractor and change order report. Nowadays, some of these activities are carried out by site supervisors (foremen), delegated by site managers, and part of this information is collected by them. Mäki and Kerosuo (2015) observed that site managers' working days are devoted to work planning and briefing including site rounds, preparing for bids and procurement, solving problems, invoicing and keeping site diaries, searching for missing information in design, and meetings. Some of these tasks require information sharing and problem solving platforms allowing the input of subcontractors, designers, materials suppliers and other site personnel.

Site diaries are one way of recording site activities being useful sources of data. They can be used for a number of purposes including dealing with claims, checking quality, controlling costs and monitoring performance (Scott and Assadi, 1999). Russell (1993) shows that site managers did not prioritize filling site diaries in their daily routines for two reasons, (i) time pressure, and (ii) the difficulty involved in making efficient use of site diaries. Russell proposes categories for the computerized daily site reporting required of a site manager in order to reduce the response time to problems, integrate site reporting with project scheduling and project planning, and allow faster updates.

ICT used to monitor activities can reduce the need for manual entries by site managers. This reduces the labour intensiveness of data collection, less time is spent on these activities and enables more frequent monitoring. Attempts have been made to automate monitoring of labour input using global positioning systems (Navon and Goldschmidt, 2003), monitoring of equipment, tower crane, materials and safety performance (Navon, 2005), materials management including planning, procurement, logistics, handling and stock and waste control using two types of input: project information from headquarters, and project progress, which is recorded using monitoring cameras placed on the construction site (Kim et al., 2013) or using automated data collection technologies involving barcodes (Navon and Berkovich, 2006). For waste management, IT support is typically used for quantification, keeping records and supporting decision making. For instance, DeconRCM (Banias et al., 2011) is a web-based decision support system enabling optimal management of building demolition and renovation waste using information on the building including construction year, dimensions and type of heating to estimate the quantity of waste. On the other hand, Kasim (2011) notes that only spreadsheet and handheld devices are used for materials management on sites and that their application is limited to planning and procurement, with other materials management activities carried out in traditional ways. Isaac and Navon (2014) question whether monitoring and control can be fully automated. They suggest that since human actions are complex and unpredictable, manual entry of data is still needed and propose a framework for semi-automation which incorporates manual data from the daily site report and assessments by team members.

This thesis does not focus on future possibilities for the automation of monitoring and control activities, which explains why advanced technologies of automation are not covered here. Instead, the focus is on ICT being used in current practice to support monitoring and problem solving, that is, technologies commonly used on construction sites for these purposes such as laptops, mobile telephones and tablets.

2.6 Extension of the framework

The framework described above was used to frame the interviews and the first questionnaire. The responses to open-ended questions were used to extend this framework for the second, larger questionnaire survey. The extended framework includes new factors such as project size, project type, project location and International Organization for Standardization (ISO) standards.

2.7 Summary and revisiting the research questions

Productivity is an important performance measure at the industry level. The construction industry suffers from low rates of productivity growth, for which the literature provides only short term explanations. Low productivity growth rates in the

construction industry can be explained by measurement errors and problems related to determining output and input qualities, which highlight the need to extend the range of performance measures at project level. This refers to the first research question which addresses the relations between construction industry productivity and measures of construction project performance.

Besides traditional performance measures (cost, schedule, quality), sustainability, especially environmental sustainability is becoming one of the widely applied project level performance dimensions in construction projects. Resource use and waste management are activities that influence environmental and economic sustainability as well as productivity, and these activities can be managed by refurbishment contractors during the refurbishment process. Therefore, monitoring these activities is important, which refers to the second research question which addresses how resource use is monitored and managed by refurbishment site managers.

Most contemporary construction sites have access to ICT tools such as laptops, printers, tablets and Internet connection. Previous studies focus on automation of monitoring on construction sites to save time and avoid manual entry by site managers, and conclude that semi-automation might be the best choice combined with manual data entry. It is important to understand site managers' media choices for monitoring which refers to the third research question addressing how resource use monitoring and management is supported by ICT tools on refurbishment sites.

3 Research approach and design

The purpose of this thesis is to investigate how construction performance is measured by focusing on refurbishment site managers' monitoring and management of resource use. The first research question, "which are the relations between construction industry productivity and measures of construction project performance?" is the starting point of this thesis and is a "what" type question. The method chosen to address this question is theoretical analysis based on a literature review. Literature review was chosen because of the many useful previous studies of construction productivity. It also allowed a linear research process, in which each step is followed by another step in a clear, logical sequence, allowing development of a frame for data collection (based on semi-structured interviews and questionnaires) to address the second and the third research questions. An explorative research design would have provided more flexibility throughout the research process, however, explorative approaches are more useful in the absence of previous literature relevant to the research questions.

3.1 Research design

The study started in August 2011 with an initial literature review. The first empirical data for the project were collected in 2013, based on short, semi-structured interviews in a pilot study (Empirical study I). Based on the outcome of the pilot study, the investigation was narrowed down to waste management and resource use monitoring. Due to the decentralized nature of refurbishment organizations, refurbishment site managers were selected as the object of investigation. Site managers play a crucial role in construction projects, although academic debate tends to underestimate their role (Polesie, 2012).

During 2015, 27 semi-structured interviews were carried out to collect empirical data on waste management at refurbishment sites. This study (Empirical study II) was intended to be followed by a questionnaire survey, to test factors influencing waste management and resource use monitoring, and factors influencing use of ICT to support these activities. Hence, Empirical study III, involved three stages: first, an initial short questionnaire administered to 15 site managers, to identify their ICT choices and the factors influencing their choices; second, short semi-structured interviews with 14 site managers to identify which ICT support was used for what purposes; and third, using data from the first two stages, a longer questionnaire was administered nationally to refurbishment site managers.

In order to increase the validity and reliability of the findings, the interviewees were selected randomly and anonymity promised, an interview guideline was used and interviews were taped, transcribed and documented. The data collection and analysis methods and choices are also explained. In Empirical study II, data were collected from multiple sources, not just site managers.

This thesis is based on both qualitative and quantitative research. Qualitative research is sometimes criticized as being too subjective, difficult to replicate and generalize, and as lacking transparency, while in quantitative research, the researcher is distant from the participants, and structured ways of data collection limit the researcher's ability to explain the relations between variables. Moreover, quantitative research is context-bounded (Bryman and Bell, 2011). A mixed research method can mitigate these difficulties. Both the second and third research questions require an understanding of actual site practices, which are captured better using a mixed methods approach. Qualitative and quantitative research are related in that results converge and support the same conclusions, results focus on different aspects of an issue, or results are contradictory (Flick, 2009). In this thesis, the questionnaire survey was used to check the results of the interviews in Empirical study II, but also to investigate ICT use on refurbishment sites. Qualitative research can be used to facilitate quantitative research by developing hypotheses, originating in the theoretical framework, for quantitative research, since qualitative research allows unstructured, open-ended data collection. In this thesis, semi-structured interviews were used to identify aspects that were measured in the questionnaire and, also, to identify causal relations between survey variables. Detailed information about the data used in this thesis and relations to the research questions and papers are presented in Table 1.

Table 1. Appended papers and data used

Papers	Empirical study	Data type	Data collection time	Number of respondents	Contribution to research questions
I	-	Literature review	-	-	RQ1
II	I	Semi-structured interviews	March-October 2013	8 interviewees	RQ2
III	II and III	Semi-structured interviews Questionnaire	February-June 2015 December 2015	27 interviewees 78 filled	RQ2 and RQ3
IV	III	Semi-structured interviews Questionnaire	March-September 2015 December 2015	14 interviewees 78 filled	RQ3

Other qualitative data collection methods used in previous relevant studies include case studies (Egbu et al., 1998; Costin et al., 2012; Davies and Harty, 2013). According to Dubois and Araujo (2007), case studies are useful for "the detailed explanation as to why particular outcomes occur". Case studies provide rich, empirical and contemporary descriptions from the investigation of a particular phenomenon

(Eisenhardt and Graebner, 2007; Yin, 2009). Multiple cases provide a stronger base for theory building, enable comparison and show whether an emergent finding is repeated consistently in several cases; multiple cases enable a broader explanation of research questions and theoretical elaboration, and create more robust, generalizable and testable theory (Eisenhardt and Graebner, 2007). Generalization from case studies is limited to theoretical generalization and not to populations (Yin, 2009); the goal is to expand and generalize theories. Refurbishment projects are expected to vary widely, and site managers' practices are expected to be subject to a number of sources of uncertainty. Therefore, instead of studying a few refurbishment projects as cases that would provide a limited set of data to explain resource use monitoring and management on refurbishment sites, the main decision makers on refurbishment sites, namely the site managers, are investigated in the empirical studies.

Ethnographic research could have been used for this investigation; it has been used in previous studies investigating construction sites and site managers (Nycyk, 2008; Löwstedt, 2015; Mäki and Kerosuo, 2015). An ethnographic researcher can play several roles depending on his or her involvement in the setting from complete participant, participant-as-observer, observer-as-participant to complete observer (Bryman and Bell, 2011). I could have spent a month at each refurbishment site as a complete observer, taking notes and observing resource use monitoring and management, waste management, and ICT use. However, data collection through ethnographic research in the construction industry can be difficult. An ethnographic study of construction sites (Nycyk, 2008) highlights several serious limitations including difficulty in gaining access, continuous need for permission, highly competitive industry, difficulty to convince management that the method is useful, need to be unobtrusive - people do not like being observed closely, employees' beliefs that the study is serving a management objective, lack of trust, time involved for project participants and problems related to confidentiality and reporting results. Thus, the choice for this thesis was not to follow an ethnographic method.

3.2 Data collection and analysis

Paper I is based on the literature review and addresses research question 1. The literature search was not a systematic review based on a set of journals and keywords, but instead was based on the traditional snowballing technique, where articles associated with construction productivity, services productivity and performance measurement were reviewed along with the articles they cited. The intention was to analyse the historical construction productivity debate since its beginnings in the 1930s.

The empirical data used in Papers II, III and IV were derived from semi-structured interviews and questionnaires, all collected by the author. Semi-structured interviews

involved mainly site managers, but included also a few project managers, site supervisors and environmental staff in order to obtain views from other levels of the organizations on company policies and relationships with clients, subcontractors and waste logistics firms. Semi-structured interviews were chosen because of the already mentioned flexibility that allows the interviewer to depart from the interview guide and to ask follow up questions and also to deviate from the ordering of the questions (Bryman and Bell, 2011). Compared to questionnaires, interviews offer flexibility while allowing the collection of deep and complex information. In-depth interviews are useful to delve into issues that should be included in the questionnaire, develop response alternatives, and learn potential respondents' views on certain topics (Blair et al., 2013). The findings from the semi-structured interviews were exploited in this way in the design of the larger questionnaire.

3.2.1 Empirical study I

The data from Empirical study I were used in Paper II. The data were collected through face-to-face interviews which lasted between 10 and 25 minutes. The interviews were semi-structured and focused on a few crucial questions. In order to reduce misunderstandings related to terminology, most interviews were conducted in Swedish with the exception of one which was conducted in English at the interviewee's request.

The choice of interview questions was based on the literature review and the questions were designed to reveal productivity and sustainability monitoring by refurbishment contractors. The interviews covered a mix of open and closed questions such as "do you follow resource use in your project?", "who is responsible for that?" and "why do you measure sustainability?".

Eight interviews were conducted in southern Sweden with participants from five construction companies involved in refurbishment projects. Five of the interviewees were site managers employed by large contractors, and three were general or site managers from SMEs. All were involved in housing refurbishment projects. The large contractors are two of the largest contractors in Sweden and are included in the Dow Jones Sustainability Index company list. The SMEs are local contractors, located in the Gothenburg area.

The interviews were recorded and transcribed to confirm the notes taken during the interviews. For the data analysis, Flick's (2009) qualitative content analysis method was adopted. A number of categories were developed based on the literature. Irrelevant questions were eliminated, while similar passages were combined and summarized.

3.2.2 Empirical study II

The data from Empirical study II were used in Paper III. They were derived from 27 semi-structured interviews with site managers (15), project managers (4), supervisors (4), environmental staff (3) and one project engineer. Interviewees were from the two large Swedish contractors involved in Empirical study I. They were working on housing and office refurbishment projects and were familiar with certification schemes such as BREEAM (Building Research Establishment's (BRE) Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design) and the Sweden Green Building Council's Miljöbyggnad (Brown et al., 2013). As already explained, the focus is on site managers and their practices since (regardless of the type of project) it is they who make the decisions at refurbishment sites. Project managers and environmental staff were interviewed to obtain views from other levels of these organizations on company policies and relationships with clients, subcontractors and waste logistics firms. Three of the interviews were group interviews involving respectively one site manager and one supervisor, one site manager and two supervisors and one site manager and a project engineer. Since the interview responses from project managers and environmental staff showed a high degree of consensus, no further interviews were held with these categories of employees.

Site managers were selected based on the criteria of at least two years' experience in residential and commercial refurbishment projects, location in south-west Sweden, and experience of working in different sized projects. The requirement of two years' experience ensured that interviewees would have participated in more than one refurbishment project.

Interviews were conducted between February and June 2015. At least 24 hours in advance, interviewees were given a short text describing the research project and a list of interview questions. Interviews lasted for 30-60 minutes, were conducted in Swedish and were taped. Interviews were face-to-face and, except for one interview, were conducted in the interviewee's office. Interviewees were promised anonymity. The interview guide began with questions about years of experience, occupation in the company and types and sizes of refurbishment projects. It comprised a mix of open-ended and closed questions, including questions about experience from earlier projects. Examples of interview questions are "What actions do you take on site to deal with waste?", "How do waste management practices differ on refurbishment sites compared to new construction?" and "Do you see a link between the contract type (traditional or design-build) and waste management practices on refurbishment sites?"

Interviews first were transcribed verbatim and then summarized for each question. Responses were categorized and relevant passages were coded.

3.2.3 Empirical study III

The third empirical study is largely independent of Empirical study II since it refers to the third rather than the second research question. A small part of the empirical data from Empirical study III was used in Paper III, the remaining data were used in Paper IV.

The data in Empirical study III were collected in several steps. First, a mini questionnaire survey on ICT use was administered to 15 site managers from the two large Swedish contractors in Empirical studies I and II, and to three site managers from SME contractors. Second, short semi-structured interviews were conducted with 11 site managers, again from the two large Swedish contractors and three site managers from SME contractors. Third, a questionnaire was developed and sent to those respondents currently or formerly responsible for refurbishment site management, in order to analyse the effects of factors identified from earlier studies and to analyse the role of ICT use in monitoring and managing resource use and waste management. The questionnaire comprised 24 questions, mainly with checkboxes which took some 5-10 minutes time on the part of respondents. The classification questions were aimed at obtaining information on respondents, their experience and age, company size and information on the two most recent refurbishment projects including size, type, location, project contract type and which media were used for eight specific activities. The survey ended by asking respondents to compare waste management efforts, materials and work hours monitoring in their most recent two projects. Reuse of survey questions in earlier studies would have allowed comparison of the results of this study with other studies and increased reliability. However, the questionnaire was developed based on the pilot survey and interviews, and none of the questions was obtained directly from the previous literature although they were inspired by earlier research. The questionnaire survey was tested on two site managers and one industry representative before being administered to the sample. Test participants interpreted the questions as intended, which ensures validity.

Information on site managers was obtained from Sverige Bygger, a company which supplies data on construction projects. The main criteria for selecting the projects were:

1. only multifamily housing and office refurbishment projects;
2. projects which started between April and October, 2015;
3. projects with a budget over 1 million SEK; smaller projects focusing only on repairs (e.g. to ventilation or lifts) were removed

Details were obtained of 270 refurbishment projects. For each project, the dataset supplied the name of a contact person and often the contact person's job title. Since the

target population was individuals with experience of refurbishment site management, it was necessary to eliminate or replace contact persons whose managerial responsibilities did not include site manager. In small firms, the owner or general manager might belong to the target population. For contractors with fewer than 50 employees, a web check was conducted on whether the firm engaged only in refurbishment; if the contact person in the dataset was not a site manager, the site manager was identified by searching the firm's web pages.

The resulting list was checked against company web pages to ensure that the managers were still working at the company and to confirm their work positions. A few projects were eliminated because the contact person appeared more than once in the dataset. Contact persons from the larger contractors, listed as working in positions other than site manager, were more difficult to replace with site managers from the same company since these firms typically employ managerial staff who work with both new construction and refurbishment, which are not easy for the outside observer to separate.

The web questionnaire survey was sent by e-mail to 232 potential respondents. Two separate e-mails were sent to improve the response rate, depending on positions listed. One email was sent to a first group, which included 46 recipients who clearly were site managers, asking them to respond via a unique link generated for their e-mail address. A second group of 186 recipients listed as working in various positions, such as project manager, regional manager, foreman or owner, received an e-mail asking them to reply to the questionnaire if they were responsible for refurbishment site management, or to forward the e-mail to (only) one colleague with this responsibility. Since the questionnaire could be returned only once through a unique link, the total number of respondents was limited to 232.

Of the 232 distributed questionnaires, 17 questionnaires were not delivered due to various reasons including incorrect e-mail addresses or the person having left the company. After two reminders, 48 complete responses and 12 partial responses were received, implying a response rate for the web questionnaire of 20% or, when undelivered questionnaires were removed, 22%.

Although online questionnaires allow quick data collection, they have shortcomings including that online questionnaire respondents tend more often to choose the "don't know" option than in-person questionnaires administered by an interviewer, and to choose more extreme responses in Likert-scale questions. They tend to have lower response rates, with less well educated and less computer literate respondents less likely to participate (Blair et al., 2013). Online questionnaires share a number of features with postal questionnaires: that they are kept short to increase the response rate; they need to be self-explanatory; they are the same for all respondents;

respondents are more likely to quit when banned from going further because of non-response to an earlier question; and lack of control over who responds to the questionnaire.

Some site managers may not have access to a computer in their workplace or might have lacked a good Internet connection. In order to understand non-respondents' choices, to minimize bias and to increase reliability, the questionnaire was sent subsequently in paper form to the non-respondents, excluding four who had unsubscribed from the web survey, but including respondents who had provided a partial response. The 180 recipients of the paper survey included 37 site managers from the first group and 143 respondents from the second group, those working in various non-site positions such as project manager, regional manager, foreman and owner. This exercise resulted in 30 postal responses (including two from participants who had submitted partial online responses) and five letters indicating that the addressee had left the company. The response rate for the postal questionnaire was 17%.

Overall, the questionnaire was sent to 232 recipients, five of whom did not receive it because they had moved to another company; 78 of whom submitted complete responses and 10 submitted partial responses. This means a response rate of 34%. Response rates for this type of questionnaire analysing ICT use in the construction industry vary between 13% and 40% (Ahuja et al., 2009; Hewage et al., 2008; Love and Smith, 2003; Samuelson and Björk, 2014). Considering that the responses from the web and postal questionnaires were similar and the respondents had similar preferences, non-respondents can be expected also to have similar preferences.

The questionnaire data were analysed using the SPSS software. The Kolmogorov-Smirnov test was used to check whether the distribution of the data is normal. The results of the test indicated violation of the assumption of normality for most of the variables. Hence nonparametric methods were employed. The Kruskal-Wallis test was then applied to compare multiple independent groups. Here the test was used to compare the medians of for instance, five types of media choices and more, less, and same waste management efforts. The Kruskal-Wallis test is typically followed by post hoc comparisons, achieved by applying the Mann-Whitney test (Pett, 1997) which allows comparison of two independent groups' medians (Field, 2009). Here, the Mann-Whitney test was used to compare the medians of for instance, web and postal responses, more and less waste management efforts and use and non-use of a medium. This combination of the Kruskal-Wallis and the Mann-Whitney tests has been used in previous studies of the construction industry (e.g. Soetanto et al., 2006; Yong and Mustaffa, 2013; Cattell et al., 2016). The significance level chosen for the Kruskal-Wallis and Mann-Whitney tests was $p<0.05$. If many pairwise comparisons are made with the Mann-Whitney test, Type I error can be faced. In order to avoid Type I error,

a Bonferroni correction was applied by simply dividing the significance level by the number of comparisons to obtain the new significance level.

3.3 Limitations

The data analysed in this thesis refer only to refurbishment contractors in Sweden. The target populations for the surveys were contractors experienced in multifamily housing and office refurbishment projects. Refurbishment projects and the activities involved might differ between Sweden and other countries. This might be due to climatic conditions (the Swedish climate is cold) and the high proportion of the aging housing stock resulting from the Swedish Million Programme. The majority of residential refurbishment projects in Sweden are focused on multifamily houses, which were built between 1965 and 1974 having similar features. These are important limitations to consider when generalizing the findings to other contexts. Also, the focus of the empirical study was refurbishment sites and refurbishment site managers, not the whole organization. The data are mostly cross-sectional. However, the questionnaire respondents were asked to compare two subsequent projects. These findings reveal a few general trends.

4 Summary of appended papers

This chapter summarizes the purposes, background, findings and contributions of the papers that form part of this thesis. Paper I and IV were authored by Sezer and Bröchner. In Paper I, the literature review and analysis were conducted jointly; In Paper IV, the empirical survey was planned and administered by Sezer and the analysis was co-written. Papers II and III were sole authored by Sezer.

4.1 Paper I – The construction productivity debate and the measurement of service qualities

Productivity growth in the construction industry is lower than in manufacturing. Several researchers have proposed short-term explanations for this low productivity growth in the construction industry. The construction industry definition determines what is measured as output. Construction industry productivity growth rates might not be accurate due to difficulties related to measuring productivity.

The aim of this paper is to review earlier construction productivity research and to compare it with more recent approaches to quality measurement used when analysing services productivity, ultimately intending to provide guidance for using performance data from construction projects.

The construction productivity debate highlights the difficulties related to determining input and output qualities. Alternative approaches, such as use of intermediate outputs, have been suggested. The debate on construction productivity focuses on industry level productivity up to the end of the 1980s; in the 1990s, the focus broadened to include the firm, the project and the activity or task levels. Examining the different levels reveals, when the data aggregated to the industry level (national statistics), the values for productivity growth are lower.

Based on the EU KLEMS (K-capital, L-labor, E-energy, M-materials, and S-purchased services) database, which provides industry level productivity growth rates, the construction industry shows productivity growth patterns comparable to industries such as business services. These two industries have similar problems related to measuring productivity including heterogeneity of inputs and outputs and the presence of co-production. This paper analyses theories of productivity based on services, to highlight the need to extend the range of construction input and output qualities.

The concepts of client productivity and client satisfaction are better developed in the services sector. Satisfaction can be included in productivity measures because it is an indicator of hidden implicit prices for various outputs characteristics. Data from multi-criteria frameworks are needed to capture input and output qualities such as customer satisfaction.

4.2 Paper II – Contractor use of productivity and sustainability indicators for building refurbishment

Refurbishment and new construction differ in several ways, including in relation to the uncertainties pertaining to the existing buildings and tenants' involvement. Productivity measurement in the construction industry is difficult owing to the difficulties involved in measuring changes in input and output quality. Regulatory requirements highlight the need for alternatives for the case of sustainable refurbishment. Since refurbishment projects are often triggered by the objective of saving energy, more attention is paid to environmental sustainability. Contractor size is one factor that might explain the existence of and need for formal productivity and sustainability policies. Large organizations can be expected to adopt formal MCS including formal personnel control, while in smaller firms the organizational culture is based on informal interactions, and personnel control systems also are informal. Larger firms tend to plan their environmental practices better than smaller firms.

From the contractors' perspective and in light of the increasing volume of refurbishment projects, it would be useful to have indicators which better reflect the characteristics of building refurbishment. However, before trying to develop new indicators for future building refurbishment projects, it is crucial to understand the nature of current productivity and sustainability indicators, and how, why or why not refurbishment contractors use them in practice. The aim of this paper is to analyse the use of building refurbishment productivity and sustainability indicators by refurbishment contractors.

The empirical basis of the paper is semi-structured interviews, which lasted between 10-25 minutes and focused on a few crucial questions. Eight semi-structured interviews were conducted in southern Sweden with participants from five construction companies involved in refurbishment projects. Five of the interviewees were site managers employed by large contractors, and three were general managers or site managers from SMEs; all were involved in housing refurbishment projects. The large contractors include two of the largest contractors in Sweden; the SMEs are local contractors located in the Gothenburg area.

Both SMEs and large contractors track resource use on refurbishment sites. Resource use is measured using cost recording systems and a few area-based key indicators. Sustainability is a new concept for refurbishment contractors. 'Waste volume' is the most frequent sustainability measure mentioned by contractors. Some SMEs have sustainability policies, but the derived routines are weak on site. For large contractors, sustainability policies are better developed and are reflected in site routines. SMEs' refurbishment technology choices are often dictated by the client's designer, with sustainability requirements included in the contract specifications. Large contractors

are usually public companies whose stakeholders expect such routines. Lack of motivation due to lack of client demand was the explanation given for failure to use sustainability measures in refurbishment projects conducted by large contractors. SMEs clearly saw little or no economic benefits from measuring sustainability.

In designing new indicators and building certification schemes, it should be noted that simple measures of productivity are easy to apply, but cannot capture the complexities of input and output quality. These new indicators should also make sustainability monitoring more attractive and demonstrate the benefits from monitoring sustainability.

4.3 Paper III – Factors influencing building refurbishment site managers' waste management efforts

Waste management in refurbishment projects can be costly and harmful to the environment. Legislation on waste management sets limits, but the construction industry produces one third of total waste in the European Union and remains one of the main contributors to waste generation. Well planned waste management can drive productivity and environmental sustainability improvements. Refurbishment organizations are decentralized which results in variety in site managers' waste management practices. The aim of this paper is to analyse the factors influencing refurbishment site managers' waste management efforts.

Factors identified in previous studies are grouped under five categories: project related, organizational and personal, technical, industry culture, and legislation. These factors include client demand, contract type, uncertain project nature, company size, environmental certification, limited physical space, blame culture, culture of waste behaviour and legislation.

The empirical basis of this study includes mixed methods of data collection. Twenty-seven semi-structured interviews were held with managers from two large contractors involved in housing and office refurbishment projects in Sweden. A web and postal questionnaire survey was sent to 232 refurbishment site managers and received a 34% response rate.

Refurbishment site managers' waste management activities include reducing waste generation, sorting, reuse, recycling and disposal of waste. Disposal of waste is the last choice of most site managers given cost and company policies. Site managers devise waste management strategies based on environmental inventories and project size. In smaller projects, waste contractors are employed only for physical support, and site managers have less flexibility due to limited physical space. Client demand heavily influence refurbishment site managers' waste management efforts, however unlike new construction, refurbishment clients seldom require green waste management to a

higher standard than is typical of large contractors generally. The interviews revealed 17 additional factors in addition to those identified in previous studies. These 17 factors mainly belong to the project related, organizational and personal, and technical factors categories and include project type, location and size, company policy, ISO standards, lack of access to elevators, lack of specially adapted containers for different types of waste, and materials becoming heavier if they are not sheltered from rain. Among the factors tested in the questionnaire survey, level of contract detail, client demand and project size, all project related factors, were confirmed to influence waste management efforts. The activities of registration of waste amounts and registration of waste sorted on site were associated with seven factors: level of contract detail, client demand, project size, ISO 14001, ISO 9001, environmental certification and limited site space.

4.4 Paper IV – ICT use for monitoring resource use on building refurbishment sites

With advances in ICT support, starting with the use of basic spreadsheets in the early 1990s, construction project performance is being monitored in some detail. The recent introduction of more complex applications including BIM, is aimed at enabling storage of detailed data on buildings. Studies show that information sharing and communication are the main drivers of ICT use, with use of complex applications still at low levels in the construction industry. Considering the UTAUT, refurbishment site managers' ICT choices might be influenced by such factors as performance expectancy, effort expectancy, social influence and facilitation conditions. The purpose of this investigation is to analyse how site managers rely on ICT to monitor resource use in refurbishment projects.

The empirical data were collected in three stages, starting with a pilot questionnaire survey administered to 15 site managers, followed by short semi-structured interviews with 14 site managers. The final stage involved a web and postal questionnaire survey administered to 232 refurbishment site managers, which received a 34% response rate. The sample includes respondents from both small and large Swedish contractors.

The results show that managerial choice of ICT tools depends more on performance expectancy of an ICT tool than on effort expectancy. Large projects are associated with more extensive ICT use, considering that it is possible to spread the cost of ICT in such projects. Site managers did not acknowledge the need to link to refurbishment clients' ICT systems. Laptops and paper based methods are the most frequent media used by refurbishment site managers. However, there is a trend towards increased use of laptops and less reliance of paper based recording. Common use of pen and paper can be explained with two reasons, pen and paper both support information sharing (use of printers) and can be used to restrict information sharing (use of pen and paper

for private notes). Use of tablets, mobile telephones and printers is minimal. Site managers' main requirements from ICT are ease of updating project information, data entry and interpretation of screen data. Although 71% of site managers indicated that they use tablets at home, their use of them at work is minimal. This might be due to problems related to data entry on tablets or to site managers not needing mobile devices to conduct their tasks including registration of work hours, waste volumes and monitoring materials use.

5 Discussion

This chapter discusses the findings in the appended papers in relation to the three research questions.

RQ1. Which are the relations between construction industry productivity and measures of construction project performance?

Productivity is a commonly used industry performance measure. According to the official statistics in many countries, construction industry productivity growth is slow and lags behind manufacturing. Explanations for low productivity growth rates in the construction industry emphasize mainly short term factors such as decline in the average age of construction workers and shifts in the construction product mix. To address the first research question, the construction productivity, services productivity and performance measurement literature was reviewed.

Paper I shows that the construction industry productivity debate focuses on three topics: the definition of “construction”, the measurement of productivity, and the factors explaining productivity growth. Until the late 1980s, economists focused on industry level productivity in the construction industry. However, by shifting the focus and including other levels, particularly project level productivity, a discrepancy between project and industry level productivity growth was identified (Goodrum and Haas, 2002). A common explanation of low productivity growth in the construction industry is lack of appropriate measures of productivity, which has led to attempts to develop better productivity measures for the industry (Crawford and Vogl, 2006; Dadi et al., 2014; Vereen et al., 2016; Vogl and Abdel-Wahab, 2014).

Analysis of the data from the EU KLEMS database shows that the construction industry presents productivity growth patterns similar to those for services. The similarities between construction and business services include heterogeneity of outputs and inputs, and co-production with customers. Paper I argues that determining changes in output and input qualities makes productivity measurement in the construction industry difficult. On the input side, the difficulty involved in determining the quality of materials, particularly in the case of “higher grade materials going into buildings ”, was recognized as early as in the 1930s (Gill, 1933). Assessing the quality of labour input due to the heterogeneity of skilled labour is a problem that is also common to services (Schreyer, 2001).

The traditional performance areas in construction projects are cost, schedule and quality. Existing measures treat construction mostly as pure production of goods and overlook the services aspect, which is strong in the case of refurbishment (Holm, 2000). The range of output and input quality indicators in construction projects needs to be extended and new indicators should include both goods related indicators and

also service related indicators such as customer satisfaction and client productivity data. Productivity measures in construction projects do not need to be complicated; data can be captured from performance measures typically used in projects.

RQ2. How is resource use monitored and managed by refurbishment site managers?

The three dimensions of sustainability - environmental, economic and social - are now beginning to influence the performance measures used in the construction industry. Resource use monitoring and management is important for sustainability and productivity in refurbishment projects. Addressing the second research question requires an overview of how resource use is monitored and managed by refurbishment site managers, which includes the activities of purchasing new construction materials, using resources efficiently, monitoring resources and managing waste.

Resource use is monitored in order to manage resources, particularly for purchasing new materials and using both materials and human resources efficiently. The study in Paper II confirms that resource use in refurbishment projects is monitored in order to maintain control over costs and scheduling, improve tender estimates and allow benchmarking among projects. At the firm level, construction contractors need resource use monitoring for management accounting purposes. The results in Paper II show that the methods used to monitor resource use on refurbishment sites are cost recording systems, relying on simple area-based key indicators (hours/m^2 and materials/m^2), and activity based costing.

The interviews in Paper II show that incorrect or insufficiently detailed original drawings and unexpected events can lead to extra activities in refurbishment projects, and recording the extra resources used as a result is difficult. Refurbishment site managers cited cost, lack of competency, lack of experience and methods, unreliable data and time constraints as problems related to monitoring resource use. Invoking lack of time can be culturally determined and may be a symptom of complex resource allocation (Engwall and Jerbrant, 2003).

Paper II identifies waste volumes as the environmental sustainability measure most commonly mentioned by refurbishment site managers. Customer satisfaction was recognized by the interviewees as a social sustainability measure, but they were unable to categorize measures related to economic sustainability. This could be explained by the short term nature of refurbishment projects and the problems involved in applying economic sustainability measures for short periods.

Waste management includes the activities of reducing waste generation, sorting, reuse, recycling and disposal. Interviews with refurbishment site managers in Paper III show that the majority see waste generation as inevitable and beyond their control, and

consider the quantity of waste from demolition as set. However, waste in construction projects can be affected by procurement (ordering excess materials), changes to design, materials handling, rework (wrong installation and removal), weather, vandalism and misplacement (Fadiya et al., 2014).

Waste sorting is the primary waste management activity on refurbishment sites. Limited site space and costs were acknowledged as important by almost all refurbishment site managers interviewed. When site space is limited, waste is often dumped in a single container and sorted at an off-site facility by a waste contractor at a cost. In addition to being costly, off-site waste sorting facilities can be a less environmentally sustainable option. According to Lu and Yuan (2012), off-site sorting facilities tend to send non-inert materials to landfill when they could have been recycled or reused.

Site managers' willingness to reuse old materials is evident, but practical difficulties limit the opportunities for reuse. In Sweden, central government encourages refurbishment projects to improve the energy performance of buildings constructed between the 1960s and the 1980s, which requires the use of new materials. In addition, the materials from buildings erected around 1970 are often of much lower quality than modern materials.

The existence of asbestos in the building, continued occupation of the building by users and the splitting of large projects into small sub-projects is not conducive to efforts to recycle waste in refurbishment projects (Hardie et al., 2011). None of the interviewees mentioned on-site waste recycling as an alternative, probably due to local negative effects including dust and noise (Lu and Yuan, 2012), and difficulties to place recycling equipment on sites (Tam, 2009). According to the interviews reported in Paper III, recycling and reuse responsibilities in Swedish refurbishment projects are frequently transferred to waste contractors.

Factors influencing refurbishment site managers' waste management efforts fall into five categories: project related factors, organizational and personal factors, technical factors, legislation, and industry culture. Compared to the previous literature, most of the additional factors identified in Paper III fall into the categories of project related and technical.

RQ3. How is resource use monitoring and management supported by ICT tools on refurbishment sites?

A Swedish longitudinal questionnaire study provides basic knowledge on the Swedish construction industry's IT maturity (Samuelson and Björk, 2014) and shows that improving communication and sharing information have been the main drivers of IT

use, while use of more complex applications, including BIM, is at a low level. The results in Paper IV show that, for refurbishment site managers, connection to a client BIM model is seen as impractical. This might be because refurbishment site managers are unwilling to share information using ICT tools and do not see any benefit from links to client systems. This might explain in part why there is little demand for ICT tools to support collaboration among the actors in refurbishment projects.

The determinants of technology acceptance, primarily usefulness and ease of use, may explain site managers' ICT choices. The short interviews reported in Paper IV indicate that performance expectancy is a stronger determinant of ICT use than effort expectancy. It seems that refurbishment site managers' main requirements related to ICT tools are ease of updating project information, data entry and interpreting screen data, similar to what Chen and Kamara (2008) note as the technical features required of mobile devices for information management on construction sites. These technical features include screen size, input methods and storage capability. Screen size is a major reason for the limited use - 7% on average according to the web and postal questionnaire - of mobile telephones on refurbishment sites. Peer pressure as defined by Lewis et al. (2003) was not found to influence ICT use among refurbishment site managers, which is likely explained by the decentralized nature of refurbishment organizations.

The results of the web and postal questionnaire show that laptops are the most frequently used medium for refurbishment site managers, and the data also suggest that there is a positive trend towards more use of laptops. This is followed by traditional pen and paper for carrying out the eight tasks included in the questionnaire, reliance varying from 3% to 40%, depending on the activity, but for problem solving, keeping site diaries and registering work hours, in particular. Paper based recording (i) supports information sharing (as with use of printers), and (ii) restricts information sharing (paper based private notes).

The gap between use of laptops and pen and paper is narrower in the context of site diaries and for problem solving. To maintain site diaries, the trend is towards greater use of laptops, implying that the gap will increase. For problem solving there is a positive trend towards the use of both these media along with mobile telephones. These trends can be explained by the nature of problem solving activities, which require easy communication, sending digital files, such as pictures, and taking notes during on-site meetings. Despite its frequent occurrence in refurbishment projects, few researchers have investigated joint problem solving when examining ICT support patterns.

An unexpected finding from the questionnaire is that 71% of site managers use tablets at home, but almost never at work. This suggests that the low level of tablet use on

refurbishment sites is not associated with site managers' ICT skills. It is more likely related to difficulty of data entry due to the need to wear safety gloves on site, or gloves to protect against low temperatures. It might also be due to site managers not feeling a strong need for mobile devices to record work hours, waste volumes and materials use. To understand ICT use requires detailed analysis of the activities performed by site managers.

6 Conclusion

The purpose of this thesis is to investigate how construction performance is measured by focusing on refurbishment site managers' monitoring and management of resource use. The findings are drawn from four papers. Paper I is a literature review analysing construction industry productivity growth and links to project performance. Paper II is a pilot study, based on short semi-structured interviews, presenting an overview of resource use and sustainability monitoring in refurbishment projects. Paper III is based on semi-structured interviews and a web and postal questionnaire, analysing factors influencing refurbishment site managers' waste management efforts. Paper IV summarizes short semi-structured interviews, a mini survey and a web and postal questionnaire, analysing how site managers rely on ICT for monitoring resource use in refurbishment projects.

Previous studies conclude that measuring productivity in the construction industry is difficult owing, particularly, to the difficulties of determining output and input qualities. The current methods used to measure productivity in the construction industry are limited to simple area-based methods and labour productivity, which do not capture changes in the quality of inputs and outputs. Refurbishment is not pure production of goods; therefore, productivity measures should also be reflecting the service element of refurbishment. Using multi-criteria frameworks and extending the range of input and output quality indicators by including client productivity and customer satisfaction surveys, could be useful.

Resource use management is a typical sustainability activity and includes resource use monitoring and waste management. Refurbishment site managers use simple area based measures, such as hours/m^2 and materials/m^2, to measure resource use. Waste management on refurbishment sites includes waste reduction, sorting, recycling, reuse and disposal. Among these activities, waste sorting is commonly practised on refurbishment sites, while the other activities are seen as difficult to carry out on site and often are handled by waste contractors. Disposal fees and off-site sorting alternatives are expensive. Site managers' waste management efforts are influenced by project related factors, organizational and personal factors, technical factors, industry culture and legislation. The level of contract detail, specific client demands related to waste management, and project size are important factors. However, these three factors are linked to other aspects; in larger projects, for instance, space may not be a problem. Waste management efforts in refurbishment projects can be improved by addressing simple technical problems including providing clear labelling of containers and ensuring shelter from rain and snow.

Among the many activities performed by refurbishment site managers, they do not prioritize resource use monitoring and management, referring to lack of time and

methods. ICT support could reduce the time spent on resource use monitoring and management. For most daily tasks, site managers rely on laptops or pen and paper. These media choices are not due to site managers' ICT skills. The tasks involved in resource use monitoring and management on refurbishment sites are not fully supported by the devices that are available.

6.1 Implications for practice

The findings from Paper I suggest that official figures indicating low construction industry productivity growth rates can be explained by mismeasurement of productivity. By measuring output and input quality in more details and taking account of the service elements of construction, it would be possible to discuss underlying construction productivity growth and how it can be improved.

Performance in construction projects is usually measured by contractors as deviations from original plans. Managers need to be aware that original schedules and budgets can suffer from subjectivity; what appears to be excellent performance might be the result of planning with low expectations. There is no clear connection between deviations and efficient resource use and, with an increased emphasis on sustainability, this is a serious practical problem.

The construction industry is one of the top contributors to waste generation, not least because of demolition activities in refurbishment projects. There are many opportunities to improve waste management efforts. Paper III showed that refurbishment site managers see waste generation as inevitable because of the demolition involved. There is potential to reduce waste by focusing on waste generated during refurbishment, by better materials handling and ordering correct quantities and sizes of new materials and components. Better project design could play an important role by allowing an integrated view of the demolition consequences of alternative designs. Waste sorting is the only waste management activity usually carried out on refurbishment sites, and sorted waste is collected by waste contractors. Collaboration between site managers and waste logistics firms, and development of specific methods for refurbishment projects of different sizes, could reduce waste and facilitate sorting. In large refurbishment projects, clear but not too specific client waste management requirements, and an appropriate level of contract detail would support waste management efforts by site managers. Reducing the gap between site managers and office staff is important since standard approaches to waste management may not take sufficient account of the heterogeneity of project needs. Waste management should be included among the performance criteria for refurbishment projects and should be monitored and rewarded. Subcontractors are often seen by site managers as creating problems related to waste management. Hence, selection of waste conscious subcontractors could improve waste management on refurbishment sites. Policies and

guidelines for projects of different sizes should be developed at least for large contractors; scale influences site managers' waste strategies.

ICT can be used to support and facilitate resource use monitoring and management on refurbishment sites. In proposing new ICT tools for refurbishment site managers, it is important to convince them of their usefulness, given that site managers seem to prioritize performance expectancy of ICT support over effort expectancy.

6.2 Implications for future research

In an organization, employees can have different views and values and with management accounting, cybernetic controls and performance measurement, an organization aims to make sure that the employee activities are aligned with organizational goals and strategies. In this study, it was confirmed that in large, decentralized structures such as project-based organizations, local managers' activities vary. Flexible organizational policies related to environmental sustainability allow managers to respond to projects with different characteristics and limitations and to clients with different requirements and standards. Therefore it is worth to study the dilemma of routinizing employees' actions in environments requiring flexibility for making decisions such as in large, project-based organizations that deliver business services.

Accounting practices differ between the firm and project levels owing to the different or competing interests in the organization. Not only in construction projects has performance traditionally referred to cost, schedule and quality. Measuring project performance as deviations from the original plans is dubious in a sustainability perspective since the actual performance is not compared with an objective standard. This inhibits benchmarking efforts and make it difficult to actually control if a manager is following an organization's goals in a project. Future research should provide more objective performance measures nevertheless recognize that projects can involve unexpected activities. Large construction firms may report on sustainability performance and other results related to firm level policies. Data on waste management and monitoring of resource use are collected otherwise mainly for invoicing purposes and to comply with legal requirements, while these data can also be used at the firm level, for instance while reporting sustainability performance. Future research could investigate how performance data from projects are used by firms and could identify new areas for the exploitation of project performance data.

It has been shown that current productivity measures for the construction industry are insufficient. Output and input qualities in construction projects should be reflected more precisely, for example, through customer satisfaction surveys and client

productivity data. The findings from studies of performance and productivity measurement in business services are useful.

Large parts of refurbishment projects are carried out by subcontractors, which makes them important actors. Information on a subcontractor’s use of internal resources is needed for resource use monitoring in construction projects and to measure the sustainability effects of materials consumption, for example. Some site managers generally are unhappy about subcontractors' contributions to waste management performance. Despite their important role in refurbishment projects, subcontractors' practices have not been examined in detail in previous studies of refurbishment, which calls for further research.

This thesis included a questionnaire to identify refurbishment site managers’ ICT choices for different tasks. The social influence constructs defined in the UTAUT model could be developed, since social influence does not arise necessarily from co-worker pressure, but can also be a result of client demand in a project context. There is an interesting element of client-contractor co-production that merits further analysis.

The statistical analysis showed only weak links between contract type (traditional/design-build) and waste practices. Future research could study reducing waste generation by integrating project design with the detailed planning of refurbishment activities on site; more efficient ICT tools for developing and using digital building information models would be desirable.

References

Abdel-Wahab, M. and Vogl, B. (2011), "Trends of productivity growth in the construction industry across Europe, US and Japan", *Construction Management and Economics,* Vol. 29 No. 6, pp. 635-644.

Adriaanse, A., Voordijk, H. and Dewulf, G. (2010), "The use of interorganisational ICT in United States construction projects", *Automation in Construction,* Vol. 19 No. 1, pp. 73-83.

Ahuja, V., Yang, J. and Shankar, R. (2009), "Study of ICT adoption for building project management in the Indian construction industry", *Automation in Construction,* Vol. 18 No. 4, pp. 415-423.

Ajayi, S.O., Oyedele, L.O., Akinade, O.O., Bilal, M., Owolabi, H.A., Alaka, H.A. and Kadiri, K.O. (2016), "Reducing waste to landfill: A need for cultural change in the UK construction industry", *Journal of Building Engineering,* Vol. 5, pp. 185-193.

Allen, S.G. (1985), "Why construction industry productivity is declining", *Review of Economics and Statistics,* Vol. 67 No. 4, pp. 661-669.

Andersen, M.S. (2007), "An introductory note on the environmental economics of the circular economy", *Sustainability Science,* Vol. 2 No. 1, pp. 133-140.

Banias, G., Achillas, C., Vlachokostas, C., Moussiopoulos, N. and Papaioannou, I. (2011), "A web-based Decision Support System for the optimal management of construction and demolition waste", *Waste Management,* Vol. 31 No. 12, pp. 2497-2502.

Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H. (2009), "Attitude and behavioral factors in waste management in the construction industry of Malaysia", *Resources, Conservation and Recycling,* Vol. 53 No. 6, pp. 321-328.

Bititci, U., Garengo, P., Dörfler, V. and Nudurupati, S. (2012), "Performance measurement: Challenges for tomorrow", *International Journal of Management Reviews,* Vol. 14 No. 3, pp. 305-327.

Blair, J., Czaja, R.F. and Blair, E.A. (2013), *Designing Surveys: A Guide to Decisions and Procedures,* Sage, Los Angeles.

Brown, N.W., Malmqvist, T., Bai, W. and Molinari, M. (2013), "Sustainability assessment of renovation packages for increased energy efficiency for multi-family buildings in Sweden", *Building and Environment,* Vol. 61, pp. 140-148.

Brown, S.A., Massey, A.P., Montoya-Weiss, M.M. and Burkman, J.R. (2002), "Do I really have to? User acceptance of mandated technology", *European Journal of Information Systems,* Vol. 11 No. 4, pp. 283-295.

Bryman, A. and Bell, E. (2011), *Business Research Methods,* Oxford University Press, Oxford.

Cattell, K., Bowen, P. and Edwards, P. (2016), "Stress among South African construction professionals: a job demand-control-support survey", *Construction Management and Economics,* Vol. 34 No. 10, pp. 700-723.

Chen, Y. and Kamara, J.M. (2008), "Using mobile computing for construction site information management", *Engineering, Construction and Architectural Management,* Vol. 15 No. 1, pp. 7-20.

Chenhall, R.H. (2003), "Management control systems design within its organizational context: findings from contingency-based research and directions for the future", *Accounting, Organizations and Society,* Vol. 28 No. 2, pp. 127-168.

Cole, R.J. (2005), "Building environmental assessment methods: redefining intentions and roles", *Building Research and Information,* Vol. 33 No. 5, pp. 455-467.

Costin, A., Pradhananga, N. and Teizer, J. (2012), "Leveraging passive RFID technology for construction resource field mobility and status monitoring in a high-rise renovation project", *Automation in Construction,* Vol. 24, pp. 1-15.

Crawford, P. and Vogl, B. (2006), "Measuring productivity in the construction industry", *Building Research and Information*, Vol. 34 No. 3, pp. 208-219.
Dacy, D.C. (1965), "Productivity and price trends in construction since 1947", *The Review of Economics and Statistics*, Vol. 47 No. 4, pp. 406-411.
Dadi, G.B., Goodrum, P.M. and Bonham, D. (2014), "A prototype master code of accounting structure to facilitate accurate measures of construction labor productivity across multiple projects", *Theoretical Economics Letters*, Vol. 4 No. 1, pp. 49-59.
Daft, R.L. and Lengel, R.H. (1986), "Organizational information requirements, media richness and structural design", *Management Science*, Vol. 32 No. 5, pp. 554-571.
Dainty, A.R., Cheng, M.-I. and Moore, D.R. (2003), "Redefining performance measures for construction project managers: an empirical evaluation", *Construction Management and Economics*, Vol. 21 No. 2, pp. 209-218.
Davies, R. and Harty, C. (2013), "Implementing 'Site BIM': A case study of ICT innovation on a large hospital project", *Automation in Construction*, Vol. 30, pp. 15-24.
Davila, T. (2005), "An exploratory study on the emergence of management control systems: formalizing human resources in small growing firms", *Accounting, Organizations and Society*, Vol. 30 No. 3, pp. 223-248.
Davis, F.D. (1989), "Perceived usefulness, perceived ease of use, and user acceptance of information technology", *MIS Quarterly*, Vol. 13 No. 3, pp. 319-340.
Djellal, F. and Gallouj, F. (2013), "The productivity challenge in services: measurement and strategic perspectives", *The Service Industries Journal*, Vol. 33 No. 3-4, pp. 282-299.
Dubois, A. and Araujo, L. (2007), "Case research in purchasing and supply management: opportunities and challenges", *Journal of Purchasing and Supply Management*, Vol. 13 No. 3, pp. 170-181.
Eccles, R.G. (1991), "The performance measurement manifesto", *Harvard Business Review*, Vol. 69 No. 1, pp. 131-137.
Egbu, C.O. (1997), "Refurbishment management: challenges and opportunities", *Building Research and Information*, Vol. 25 No. 6, pp. 338-347.
Egbu, C.O. (1999), "Skills, knowledge and competencies for managing construction refurbishment works", *Construction Management and Economics*, Vol. 17 No. 1, pp. 29-43.
Egbu, C.O., Young, B.A. and Torrance, V.B. (1998), "Planning and control processes and techniques for refurbishment management", *Construction Management and Economics*, Vol. 16 No. 3, pp. 315-325.
Eisenhardt, K.M. and Graebner, M.E. (2007), "Theory building from cases: Opportunities and challenges", *Academy of Management Journal*, Vol. 50 No. 1, pp. 25-32.
Engwall, M. and Jerbrant, A. (2003), "The resource allocation syndrome: the prime challenge of multi-project management?", *International Journal of Project Management*, Vol. 21 No. 6, pp. 403-409.
Eurostat (2016), "Waste statistics", available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics (accessed 31 May 2016).
Fadiya, O.O., Georgakis, P. and Chinyio, E. (2014), "Quantitative Analysis of the Sources of Construction Waste", *Journal of Construction Engineering*, Vol. 2014, doi: 10.1155/2014/651060.
Feltham, G.A., Hofmann, C. and Indjejikian, R.J. (2015), "Performance Aggregation and Decentralized Contracting", *The Accounting Review*, Vol. 91 No. 1, pp. 99-117.
Fiedler, K. (1987), "Special conditions for time scheduling of building modernization process", *International Journal of Project Management*, Vol. 5 No. 1, pp. 35-38.
Field, A. (2009), *Discovering Statistics Using SPSS*, Sage, London.
Flick, U. (2009), *An Introduction to Qualitative Research*, Sage, London.

Forsberg, A. (2008), "Produktivitetsmätningar som förbättringsverktyg : en kartläggning av arbetsproduktivitetsmätningar på svenska byggarbetsplatser", Licentiate thesis, Dept of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, Luleå.

Gill, C. (1933), "Construction statistics", *Journal of the American Statistical Association,* Vol. 28 No. 181, pp. 31-54.

Gluch, P. and Räisänen, C. (2012), "What tensions obstruct an alignment between project and environmental management practices?", *Engineering, Construction and Architectural Management,* Vol. 19 No. 2, pp. 127-140.

Goodrum, P.M. and Haas, C.T. (2002), "Partial factor productivity and equipment technology change at activity level in US construction industry", *Journal of Construction Engineering and Management,* Vol. 128 No. 6, pp. 463-472.

Griliches, Z. (1992), "Introduction", in Griliches, Z. (Ed.), *Output Measurement in the Service Sectors,* University of Chicago Press, Chicago, pp. 1-22.

Guenther, E., Endrikat, J. and Guenther, T.W. (2016), "Environmental management control systems: A conceptualization and a review of the empirical evidence", *Journal of Cleaner Production,* Vol. 136, pp. 147-171.

Hardie, M., Miller, G. and Khan, S. (2011), "Waste minimisation in office refurbishment projects: an Australian perspective", *Open Waste Management Journal,* Vol. 4, pp. 21-27.

Hewage, K.N., Ruwanpura, J.Y. and Jergeas, G.F. (2008), "IT usage in Alberta's building construction projects: Current status and challenges", *Automation in Construction,* Vol. 17 No. 8, pp. 940-947.

Hill, R.C. and Bowen, P.A. (1997), "Sustainable construction: principles and a framework for attainment", *Construction Management and Economics,* Vol. 15 No. 3, pp. 223-239.

Holm, M.G. (2000), "Service management in housing refurbishment: a theoretical approach", *Construction Management and Economics,* Vol. 18 No. 5, pp. 525-533.

Isaac, S. and Navon, R. (2014), "Can project monitoring and control be fully automated?", *Construction Management and Economics,* Vol. 32 No. 6, pp. 495-505.

Jääskeläinen, A. and Laihonen, H. (2014), "Applying performance measurement in service operations: analysis of contextual differences", *International Journal of Business Performance Management,* Vol. 15 No. 3, pp. 243-261.

Kamaruzzaman, S.N., Lou, E.C.W., Zainon, N., Zaid, N.S.M. and Wong, P.F. (2016), "Environmental assessment schemes for non-domestic building refurbishment in the Malaysian context", *Ecological Indicators,* Vol. 69, pp. 548-558.

Kasim, N. (2011), "ICT implementation for materials management in construction projects: case studies", *Journal of Construction Engineering and Project Management,* Vol. 1 No. 1, pp. 31-36.

Kim, C., Park, T., Lim, H. and Kim, H. (2013), "On-site construction management using mobile computing technology", *Automation in Construction,* Vol. 35, pp. 415-423.

Lewis, W., Agarwal, R. and Sambamurthy, V. (2003), "Sources of influence on beliefs about information technology use: An empirical study of knowledge workers", *MIS Quarterly,* Vol. 27 No. 4, pp. 657-678.

Li, M. (2012), "A waste management system for small and medium enterprises engaged in office building retrofit projects", PhD Thesis, School of Civil Engineering and Built Environment, Queensland University of Technology, Brisbane.

Li, M. and Yang, J. (2014), "Critical factors for waste management in office building retrofit projects in Australia", *Resources, Conservation and Recycling,* Vol. 93, pp. 85-98.

Ling, Y.Y. and Tan, F. (2015), "Selection of site supervisors to optimize construction project outcomes", *Structural Survey,* Vol. 33 No. 4/5, pp. 407-422.

Lingard, H., Graham, P. and Smithers, G. (2000), "Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation", *Construction Management and Economics*, Vol. 18 No. 4, pp. 383-393.

Love, P.E. and Smith, J. (2003), "Benchmarking, benchaction, and benchlearning: rework mitigation in projects", *Journal of Management in Engineering*, Vol. 19 No. 4, pp. 147-159.

Löwstedt, M. (2015), "'Taking off my glasses in order to see': exploring practice on a building site using self-reflexive ethnography", *Construction Management and Economics*, Vol. 33 No. 5-6, pp. 404-414.

Lu, W. and Yuan, H. (2012), "Off-site sorting of construction waste: What can we learn from Hong Kong?", *Resources, Conservation and Recycling*, Vol. 69, pp. 100-108.

Lueg, R. and Radlach, R. (2016), "Managing sustainable development with management control systems: A literature review", *European Management Journal*, Vol. 34 No. 2, pp. 158-171.

Malmgren, L. (2014), "Industrialized construction-explorations of current practice and opportunities", PhD Thesis, Faculty of Engineering, Lund University, Lund.

Malmi, T. and Brown, D.A. (2008), "Management control systems as a package—Opportunities, challenges and research directions", *Management Accounting Research*, Vol. 19 No. 4, pp. 287-300.

Malmi, T. and Granlund, M. (2009), "In search of management accounting theory", *European Accounting Review*, Vol. 18 No. 3, pp. 597-620.

Mangold, M., Österbring, M., Wallbaum, H., Thuvander, L. and Femenias, P. (2016), "Socio-economic impact of renovation and energy retrofitting of the Gothenburg building stock", *Energy and Buildings*, Vol. 123, pp. 41-49.

Mansfield, J.R. (2002), "What's in a name? Complexities in the definition of "refurbishment"", *Property Management*, Vol. 20 No. 1, pp. 23-30.

McAdam, R. and Bailie, B. (2002), "Business performance measures and alignment impact on strategy: The role of business improvement models", *International Journal of Operations and Production Management*, Vol. 22 No. 9, pp. 972-996.

McKim, R., Hegazy, T. and Attalla, M. (2000), "Project performance control in reconstruction projects", *Journal of Construction Engineering and Management*, Vol. 126 No. 2, pp. 137-141.

Mickaityte, A., Zavadskas, E.K., Kaklauskas, A. and Tupenaite, L. (2008), "The concept model of sustainable buildings refurbishment", *International Journal of Strategic Property Management*, Vol. 12 No. 1, pp. 53-68.

Mäki, T. and Kerosuo, H. (2015), "Site managers' daily work and the uses of building information modelling in construction site management", *Construction Management and Economics*, Vol. 33 No. 3, pp. 163-175.

Navon, R. (2005), "Automated project performance control of construction projects", *Automation in Construction*, Vol. 14 No. 4, pp. 467-476.

Navon, R. and Berkovich, O. (2006), "An automated model for materials management and control", *Construction Management and Economics*, Vol. 24 No. 6, pp. 635-646.

Navon, R. and Goldschmidt, E. (2003), "Can labor inputs be measured and controlled automatically?", *Journal of Construction Engineering and Management*, Vol. 129 No. 4, pp. 437-445.

Nycyk, M. (2008), "Records management practices in construction industries: Australian perspectives", *Records Management Journal*, Vol. 18 No. 2, pp. 140-149.

Olsson, S., Malmqvist, T. and Glaumann, M. (2015), "Managing sustainability aspects in renovation processes: Interview study and outline of a process model", *Sustainability*, Vol. 7 No. 6, pp. 6336-6352.

OECD (2001), *Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth,* Organisation for Economic Cooperation and Development, Paris.

Osmani, M., Glass, J. and Price, A.D. (2008), "Architects' perspectives on construction waste reduction by design", *Waste Management,* Vol. 28 No. 7, pp. 1147-1158.

Passmore, J. (1980), *Man's Responsibility for Nature,* Duckworth, London.

Pett, M.A. (1997), *Nonparametric Statistics for Health Care Research: Statistics for Small Samples and Unusual Distributions,* Sage, London.

Polesie, P.M. (2011), "Improving productivity in construction : a contractor perspective", Licentiate thesis, Dept of Civil and Environmental Engineering, Chalmers University of Technology, Gothenburg.

Polesie, P.M. (2012), "Reducing the use of resources in medium-sized Swedish construction enterprises: production managers' views", *Construction Management and Economics,* Vol. 30 No. 3, pp. 193-202.

Poon, C.S., Yu, A.T.W., Wong, A. and Yip, R. (2013), "Quantifying the impact of construction waste charging scheme on construction waste management in Hong Kong", *Journal of Construction Engineering and Management,* Vol. 139 No. 5, pp. 466-479.

Rahmat, I.B. (1997), "The planning and control process of refurbishment projects", PhD Thesis, Faculty of the Built Environment, University of London, London.

Ruddock, L. and Ruddock, S. (2011), "Evaluation of trends in the UK construction industry using growth and productivity accounts", *Construction Management and Economics,* Vol. 29 No. 12, pp. 1229-1239.

Russell, A.D. (1993), "Computerized daily site reporting", *Journal of Construction Engineering and Management,* Vol. 119 No. 2, pp. 385-402.

Samuelson, O. and Björk, B.-C. (2014), "A longitudinal study of the adoption of IT technology in the Swedish building sector", *Automation in Construction,* Vol. 37, pp. 182-190.

Schreyer, P. (2001), "The OECD productivity manual: a guide to the measurement of industry-level and aggregate productivity", *International Productivity Monitor,* Vol. Spring No. 2, pp. 37-51.

Scott, S. and Assadi, S. (1999), "A survey of the site records kept by construction supervisors", *Construction Management and Economics,* Vol. 17 No. 3, pp. 375-382.

Shen, L.Y., Li Hao, J., Tam, V.W.Y. and Yao, H. (2007), "A checklist for assessing sustainability performance of construction projects", *Journal of Civil Engineering and Management,* Vol. 13 No. 4, pp. 273-281.

Soetanto, R., Dainty, A.R., Glass, J. and Price, A.D. (2006), "Towards an explicit design decision process: the case of the structural frame", *Construction Management and Economics,* Vol. 24 No. 6, pp. 603-614.

Son, H., Park, Y., Kim, C. and Chou, J.-S. (2012), "Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model", *Automation in Construction,* Vol. 28, pp. 82-90.

Stokes, H.K. (1981), "An examination of the productivity decline in the construction industry", *The Review of Economics and Statistics,* Vol. 63 No. 4, pp. 495-502.

Styhre, A. (2006), "The bureaucratization of the project manager function: The case of the construction industry", *International Journal of Project Management,* Vol. 24 No. 3, pp. 271-276.

Styhre, A. (2008), "Coaching as second-order observations: Learning from site managers in the construction industry", *Leadership and Organization Development Journal,* Vol. 29 No. 3, pp. 275-290.

Styhre, A. and Josephson, P.E. (2006), "Revisiting site manager work: stuck in the middle?", *Construction Management and Economics*, Vol. 24 No. 5, pp. 521-528.

Tam, V.W. (2009), "Comparing the implementation of concrete recycling in the Australian and Japanese construction industries", *Journal of Cleaner Production*, Vol. 17 No. 7, pp. 688-702.

Tenah, K.A. (1986), "Construction personnel role and information needs", *Journal of Construction Engineering and Management*, Vol. 112 No. 1, pp. 33-48.

Teo, M.M.M. and Loosemore, M. (2001), "A theory of waste behaviour in the construction industry", *Construction Management and Economics*, Vol. 19 No. 7, pp. 741-751.

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G. (2015), "Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: benefits and limitations", *International Journal of Construction Management*, Vol. 15 No. 2, pp. 137-147.

Venkatesh, V., Morris, M.G., Davis, G.B. and Davis, F.D. (2003), "User acceptance of information technology: Toward a unified view", *MIS Quarterly*, Vol. 27 No. 3, pp. 425-478.

Vereen, S.C., Rasdorf, W. and Hummer, J.E. (2016), "Development and comparative analysis of construction industry labor productivity metrics", *Journal of Construction Engineering and Management*, Vol. 142 No. 7, doi: 10.1061/(ASCE)CO.1943-7862.0001112, 04016020.

Withana-Gamage, I.S. (2011), "A waste minimisation framework for the procurement of design and build construction projects", Doctoral Thesis, Civil and Building Engineering, Loughborough University, Loughborough.

Vogl, B. and Abdel-Wahab, M. (2014), "Measuring the Construction Industry's Productivity Performance: Critique of International Productivity Comparisons at Industry Level", *Journal of Construction Engineering and Management*, Vol. 141 No. 4, doi: 10.1061/(ASCE)CO.1943-7862.0000944, 04014085.

Yin, R.K. (2009), *Case Study Research: Design and Methods*, Sage, London.

Yong, Y.C. and Mustaffa, N.E. (2013), "Critical success factors for Malaysian construction projects: an empirical assessment", *Construction Management and Economics*, Vol. 31 No. 9, pp. 959-978.

Yu, A.T., Poon, C., Wong, A., Yip, R. and Jaillon, L. (2013), "Impact of construction waste disposal charging scheme on work practices at construction sites in Hong Kong", *Waste Management*, Vol. 33 No. 1, pp. 138-146.

Yun, S., Choi, J., de Oliveira, D.P. and Mulva, S.P. (2016), "Development of performance metrics for phase-based capital project benchmarking", *International Journal of Project Management*, Vol. 34 No. 3, pp. 389-402.