THESIS FOR THE DEGREE OF LICENTIATE OF TECHNOLOGY

Contractor Monitoring of Productivity and Sustainability in Building Refurbishment

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Abstract

The aging building stock in Europe and regulatory requirements to decrease energy consumption make sustainable refurbishment a valuable alternative to other construction activities. The construction industry appears to suffer from low productivity growth, and the construction productivity debate concludes that productivity measurement is difficult, not least due to changes in input and output qualities. Building certification schemes are one way to measure sustainability. However, existing schemes focus mainly on environmental sustainability and new construction, while refurbishment differs from new construction. The purpose of this research is to analyse the relation between the theoretical concepts of sustainability and productivity in the context of measurement, and to investigate the performance measures used in housing and office refurbishment projects.

This thesis is based mainly on literature reviews in the areas of sustainability, productivity, performance measurement and building refurbishment. The empirical data were collected through eight semi-structured interviews - five with site managers employed by large contractors, and three with general or site managers from small and medium sized enterprises (SMEs). All the interviewees were involved in housing refurbishment projects.

The findings of this thesis suggest that current methods of measuring productivity in the construction industry are unsatisfactory. Simple area-based methods and measurement of labour productivity do not capture changes in input and output qualities. Most existing building certification schemes have not taken account of the overall sustainability of the refurbishment process. They reflect the fundamentals of sustainability very poorly, and they tend to hide conflicts between sustainability and productivity. They mostly lack a clear refurbishment focus, even in schemes that are supposed to include refurbishment. Lack of time is a frequent excuse for not measuring productivity on sites, although perceived time pressure might be a symptom of complex resource allocation. SMEs pay little attention to sustainability measurement because they do not see it providing economic benefits, while large contractors invoke lack of client demand.

Keywords: *productivity, sustainability, measurement, refurbishment, construction industry*

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Göteborg, April 2014

Ahmet Anıl Sezer

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Sezer, A.A. and Bröchner, J. (forthcoming), Construction Management and Economics, doi: 10.1080/01446193.2013.831464.

Paper II – Environmental assessment tools and efficiency in housing and office refurbishment

Sezer, A.A. (2012), In Proc. ARCOM 2012 – 28th Annual Conference, Edinburgh, 3-5 September 2012. p. 1331-1341.

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

Sezer, A.A., submitted to a scientific journal, under second round of review.

1 Introduction

Chapter 1 provides a general introduction to the research and the research problem, and discusses the research purpose and formulates the thesis' research questions. The scope and structure of the thesis and thesis structure are also outlined.

The aging building stock in Europe and regulatory requirements to decrease energy consumption make sustainable refurbishment a valuable alternative to demolition and new construction. With the exception of a few studies (see e.g. Egbu, 1997; McKim et al., 2000), the contractor perspective on refurbishment production processes has been mostly ignored by earlier research. Refurbishment differs from new construction and the uncertainties pertaining to the existing building as well as the involvement of tenants are just two of these differences. A study of sustainability and productivity measurement for refurbishment needs to consider these differences.

The construction industry has been shown to have low productivity growth rates. Most construction productivity research is at the industry level, and very early attempts to explain low productivity growth in the industry (Allen, 1985; Dacy, 1965; Stokes, 1981) do not go beyond short or medium term explanations. In the 1990s, the focus shifted to the firm, project and activity levels. Analysing these different levels shows that construction practitioners who are actively involved in the construction process are often surprised by industry level national statistics, since they think that improvement of productivity is within their own span of control (Rojas and Aramvareekul, 2003).

Productivity is defined as "a ratio of volume measure of output to a volume measure of input use" (OECD, 2001, p.11). Measuring productivity in the construction industry is difficult because of changing qualities (values of attributes). In order to avoid difficulties associated with input and output, Kaplan (1959) proposes the use of intermediate outputs such as cubic yards of concrete foundation; however, for refurbishment, intermediate outputs are difficult to identify. The output measurement problem overlaps with services sector (Griliches, 1992). Especially refurbishment is not the pure production of goods and compared to other construction activities; its service characteristics are more obvious (Holm, 2000). Therefore, in order to measure productivity, the range of input and output quality indicators needs to be extended.

Today, the concept of sustainability is considered to have at least three dimensions: environmental, economic and social. One way to measure sustainability in the construction industry is to use building certification schemes. However, existing building certification schemes are insufficient in many ways. Although Cole (2005) estimates a shift from environmental focus to a wider sustainability focus, Berardi's (2012) study notes that almost all building assessment systems still lack economic and social aspects. Moreover, most existing building certification schemes generally lacked a clear refurbishment focus, although special versions for refurbishment have begun to emerge.

The development of new indicators to be included in assessment systems for sustainable refurbishment presents various problems. From an ecologist perspective, Passmore (1980)

refers to the conservationist and preservationist views. Applying the preservationist view to refurbishment projects highlights the problem of waste. Refurbishment projects also promote several types of conflicts. While refurbishment brings global, long term, positive benefits such as decreased CO_2 emissions, the local, short term, negative effects, such as dust and noise, that occur during the refurbishment process cannot be disregarded.

There might be conflicts among dimensions of sustainability in a refurbishment context. For instance, in energy efficiency refurbishment projects, the goal is to decrease energy use and, provide positive environmental results. It is well known that refurbishment increases property values and (usually) rents, which produces positive economic results for the property owner, but could be harmful to social sustainability, namely for tenants due to possible rent increases.

Finally, during the refurbishment process, especially in office refurbishment projects, local, negative disruptions decrease user satisfaction (Holm and Bröchner, 2000), which may have an influence on their productivity and translate to reduced economic and social sustainability. The conflict between process efficiency and economic sustainability is an issue that needs to be addressed. By efficiency is here meant "the degree to which a production process reflects best practice" (OECD, 2001, p.124). Efficiency reflects the short term productivity of the refurbishment process, while economic sustainability refers to its long term consequences.

1.1 Purpose and research questions

The purpose of this thesis is to analyse the relation between the theoretical concepts of sustainability and productivity in the context of measurement and to investigate the performance measures used in housing and office refurbishment projects. In response to this purpose, two research questions have been formulated:

R1. How are sustainability and productivity measured by contractors in refurbishment projects?

R2. Which principles could be followed to reconcile sustainability and productivity in a refurbishment context?

1.2 Scope

This study analyses productivity and sustainability measurement in multi-family housing and office refurbishment projects in Sweden, from the contractors' perspective.

1.3 Thesis structure

Chapter 2 presents the theoretical framework of the thesis starting with performance measurement, followed by productivity measurement and sustainability measurement. Chapter 3 presents the research design, and data collection and method choices, and concludes by discussing some limitations identified in the thesis. The appended papers are summarised in Chapter 4. Chapter 5 discusses the research findings and their relevance to the research questions. Chapter 6 provides the conclusions, and Chapter 7 proposes areas for future research.

2 Theoretical framework

This chapter present, the theoretical basis of this thesis including critical reviews in the areas of performance measurement, productivity measurement and sustainability measurement.

2.1 Performance measurement

Firm level performance is measured by firms for obvious reasons including the rewards tied to performance measures, benchmarking to check the focal firm's progress and that of its competitors in order to develop and evaluate new strategies (Eccles, 1991), to communicate with the consumers (Schweber, 2013; Crawley and Aho, 1999) and to satisfy regulatory requirements (Tam et al., 2006). Behn (2003) identifies eight areas where public managers use performance measures – evaluation, control, budgeting, motivating, promoting, celebrating, learning and improvement, that is, to improve performance, which is the real purpose of performance measures to which the other seven areas contribute. Project managers and executives perceive performance measures differently, explained by the difference between a project level focus and a company-wide focus (Cox et al., 2003).

Cost, schedule and quality are the main construction industry performance areas. In a comparative of study of performance measurement in refurbishment and new construction, McKim et al. (2000) argue that new construction projects perform better than refurbishment projects on cost, schedule and quality. This is explained by the difficulties associated with refurbishment projects: 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, occupants had substantially more complaints in refurbishment projects about dust, noise and smoke nuisance.

Contractor size is one factor that explains the existence of and need for formal productivity and sustainability policies. Davila (2005), in his study of small, young and technology-oriented firms, identifies size as related to the adoption of management control systems, over a range of firm sizes. As well as external factors, internal factors such as managerial incentives, organisational culture and organisational identity can determine environmental decisions. Howard-Greenville et al. (2008) find a positive relationship between firms' participation in voluntary environmental practices and managerial incentives. A study of manufacturing companies shows that larger firms tend to plan their environmental practices better than smaller firms (Darnall et al., 2010). Regulatory compliance, auditing activities and resources consumption are identified as factors influencing the level of environmental management in the construction industry, although the authors confirm that regulatory compliance is the strongest factor (Tam et al., 2006). Gluch et al. (2009) revise and develop the absorptive capacity model for green innovations and highlight three predictors that increase organisations' capacity to absorb green innovations: acquisition (routines to identify demands, initial reviews), assimilation (measurable goals, action plans, life cycle assessment), and transformation (audits, environmental declarations).

Environmental management trends in Sweden are identified in a recent study (Gluch et al., 2013) which argues that organisations are facing less pressure of legislative measures, but are under more pressure from stakeholders about environmental issues. Gluch et al.'s (2013) study is based on questionnaires sent to the environmental managers of construction companies, including contractors with at least 50 employees in different years, in 2002, 2006 and 2010. The authors argue that over this period, environmental management activities increased; however, they find no obvious link between these activities and business performance which includes increased profit, competitiveness and productivity. Clearly, increased stakeholder pressure led to the expanded role of environmental managers, and the inclusion of environmental managers in the top management team, who influenced construction site routines through company strategies.

2.2 Productivity measurement

According to official statistics in many countries, the construction industry is associated with low productivity growth rates. Inspired by the introduction of the EU KLEMS database (Timmer et al., 2010), cross industry comparisons, international comparisons (Abdel-Wahab and Vogl, 2011) and evaluations of growth trends (Ruddock and Ruddock, 2011) have been conducted. By observing industry specific productivity growth patterns, a relationship between the construction industry and business services is highlighted while most types of manufacturing remains far from the construction industry.

National statistics at the industry level often come as a surprise to construction industry practitioners who are actively involved in the construction process and consider that productivity improvements are within their own span of control. Several attempts have been made to explain low productivity growth through the provision of lists of determinants that increase construction productivity. In a pioneering article, Dacy (1965) lists shifts in construction product mix, geographical distribution (different design and building codes in different US states), increase in construction firm size in contract construction, introduction of new techniques, decline in average age of construction workers and increase in capital per worker. Although this list is useful, it does not go beyond short term explanations for low productivity growth.

Productivity is defined in this thesis as a traditionally measured ratio of output to input depending on market prices. In construction projects partial productivity often is measured as labour productivity, machine productivity, materials consumption, or even – and stretching the interpretation of productivity - as actual versus budgeted hours. Compared to new construction, the service nature of refurbishment is strong (Holm, 2000). Therefore, use of physical units as outputs, such as cubic yards of concrete laid, is not appropriate. Also, the difficulties involved in determining inputs due to their varying quality, such as quality of labour, are evident. The idea of using intermediate outputs is also considered problematic.

Client productivity is one of the input qualities in services. Nachum (1999) proposed that client productivity should be measured as labour resources and Djellal and Gallouj (2013) highlight client quality as one of the factors influencing service productivity. The meaning of term "client" is more complicated in refurbishment projects than in services. In the former,

both the owners of dwellings and their tenants are included in the term. This complication has consequences for measuring one output quality, namely customer satisfaction. These problems related to refurbishment are not considered in existing schemes.

A major difference between refurbishment and new construction is that the stakeholders are often present in the building while refurbishment work is ongoing. Especially in the case of office refurbishment projects, the local, negative disruptions caused by the refurbishment work decrease user satisfaction (Holm and Bröchner, 2000). This can have an influence on their productivity and can translate to reduced economic and social sustainability. In addition, interactions between office staff (tenants) and the craftsmen working on a refurbishment project and problems associated with materials storage, can have negative consequences for refurbishment productivity from the narrow perspective of the contractor.

Although productivity measures are insufficient, why do firms not invest more on productivity measurement? In a recent study, Walsh et al. (2013) identify links between investment in productivity gains and degree of productivity measurement in large service firms. However, firms deploy resources to monitor productivity until the marginal gains from productivity monitoring equate to the marginal costs.

2.3 Sustainability measurement

The popular use of the term “sustainability” refers to three dimensions: social, economic and environmental, as mentioned earlier; however, earlier writers have operated with more dimensions. Hill and Bowen (1997) propose two additional dimensions to social and economic sustainability: biophysical sustainability and technical sustainability. Furthermore, Mickaityte et al. (2008) summarise the expected results of a sustainable refurbishment as energy savings, increased comfort, healthier working environment, extended building life cycle, economical exploitation and environmental protection.

Use of building certification schemes is one way of measuring sustainability in the construction industry. According to Cole (2005), the role of building certification schemes has shifted from providing only objective evaluation of resource use, ecological loadings and indoor environmental quality, to including the wider, sustainability context. Cole (2005) identifies shifts in roles: objective evaluation of performance, providing design guidelines, encouraging dialogue between project actors, and transforming the market towards higher sustainability.

The original versions of building certification schemes often aimed at an ideal, artificial, new building. The later inclusion of a number of sub tools modified these original measures considering other construction activities and types. Berardi (2012) compares six certification schemes and finds energy efficiency to be the most important category which receives the highest weights. However, in the same study, he identifies that the energy performance of certified buildings is disappointing. Existing schemes often evaluate the finished building, while Kaatz et al. (2006) identify quality of social and technical processes as the areas that should be emphasised in building certification schemes. The environment is highlighted as the most important aspect of sustainable development, and existing certification schemes are

criticised for inadequate consideration of environmental effects. Todd and Geissler (1999) highlight that a building certification scheme should have global standards while including flexibility for adaptation to regional differences. Therefore, in building certification schemes, the balance between global and regional concerns is critical. Ding (2008) defines eight unsatisfactory aspects of building certification schemes: usability as a design guideline, usability for selection of optimum project options, financial aspects, recognizing regional variations, complexity (input), evaluation of qualitative and quantitative data, weighting and measurement scales. Haapio and Viitaniemi (2008) categorise building certification schemes according to the following characteristics: types of buildings assessed, users of the tools, phases in the life cycle, tools databases, and the forms of the results used.

Refurbishment apparently differs from new construction. For environmental sustainability, Passmore (1980) proposes two perspectives: conservationist and preservationist. The conservationist view is built on achieving intergenerational equity and social capital is accepted as substitutable. The preservationist view presents a more pessimistic picture and is aimed at preserving species and wilderness as they are because social capital is not substitutable and intergenerational equity is disregarded. The conservationist view has similarities with the anthropocentric view, while the preservationist view is more biocentric. Robinson (2004) confirms that one of the milestones in defining sustainability, namely the Brundtland report, is anthropocentric. Applying conservationist and preservationist views to refurbishment projects raises interesting questions. Since social capital is not substitutable in the preservationist view, both resource use and waste should be highlighted in a refurbishment context.

The best developed firm indicators are financial indicators; long before the introduction of sustainability, companies measured their economic performance. However, an analysis of the economic sustainability of refurbishment needs to highlight the difference between efficiency and economic sustainability. Efficiency reflects the short term productivity of the refurbishment process, while economic sustainability refers to its long term consequences. A cheap, efficient solution could increase productivity in the short term, while having negative consequences for all three sustainability dimensions.

In the context of refurbishment, there are conflicts between other dimensions of sustainability. For instance, in energy efficiency refurbishment (retrofit) projects, the goal is to decrease energy use and, thus, provide positive environmental results. It is well known that refurbishment increases property values and (usually) rents, which produces positive economic results for the property owner, but could be harmful to social sustainability. Also, while sustainable refurbishment is aimed at providing long term, global, positive environmental effects by decreasing energy usage and CO_2 emissions, there are short term, local, negative environmental effects, such as dust and noise, that cannot be disregarded.

3 Research method

This chapter presents the methodological choices made in this thesis. It begins with the description of the research design and continues with detailed explanation of empirical data collection and analysis methods.

3.1 Research design

The research process adopted in this thesis has similarities with the deductive research process described in Spens and Kovács (2006), and the linear research process model proposed by Flick (2009, p.95). As both models suggest, the research started with a number of intensive literature reviews from which a list of hypotheses was developed although these hypotheses are not tested formally. Instead, semi-structured interviews were conducted to obtain a snapshot of practice, and to improve the hypotheses. The literature reviews began in 2011 and Paper II was submitted in June 2012; Paper I was submitted in May 2013. The interviews were conducted between March and October 2013 and resulted in Paper III which was submitted in February 2014.

The research design adopted in this thesis includes elements of both quantitative and qualitative research strategies. While the traditional quantitative research process is defined as a linear research process (Flick, 2009), Bryman and Bell (2011) provide examples of qualitative research strategies used for testing rather than generating theories. This thesis adopts a linear research process and includes the qualitative research method of interviewing, which is considered appropriate for the type (how, which) of research questions that indicate a qualitative approach.

As already mentioned, literature reviews dominate this thesis. The literature in the relevant areas of sustainability, productivity, refurbishment, key performance indicators and performance measurement was critically reviewed. The approach fits the systematic literature review process described by Bryman and Bell (2011). Journal articles and books were identified through a backwards and forwards snowballing technique. Beginning with a small set of frequently cited articles, the publications cited in these articles were traced as were more recent publications that also cite them.

3.2 Data collection and analysis

The empirical data for Paper III in this thesis were collected through face to face interviews which lasted between 10 and 25 minutes. The interviews were semi-structured, according to the line between structured and semi-structured interviews proposed in Bryman and Bell (2011). However, although they were semi-structured, the interviews focused on a few crucial questions. Given the specialized and sometimes company-specific terminology, difficulties related to understanding questions could be resolved immediately in the semi structured interviews, ensuring higher quality responses and higher validity than in a mail survey. In order to reduce misunderstandings related to terminology, most interviews were conducted in Swedish with the exception of one that was conducted in English at the interviewee's request.

The choice of interview questions was based on the earlier literature reviews and the questions were designed to reveal the use of productivity and sustainability measures in practice 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 include 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 earlier theoretical studies. Irrelevant passages were skipped, while similar passages were combined and summarised.

3.3 Limitations

The amount of empirical data collected is small and limited to companies located in southern Sweden. Also, interviewees discussed their experiences in relation to multifamily housing refurbishments not office refurbishments.

The interview survey reported in Paper III is based on interviews with managers at various levels in contractor organisations, depending on company size. Interview results might show greater efforts of monitoring than average for firms of the same size, because respondents were nominated by representatives of large firms, and smaller firms were identified through the local office of the Swedish Construction Industries Federation.

4 Summary of appended papers

This chapter summarises the content of the papers included in this thesis. The summaries cover the purpose, background, findings and contributions of the papers. Paper I is authored by Sezer and Bröchner; Papers II and III are 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 and researchers have provided short-term and long-term explanations for low productivity growth in the construction industry. The definition of the construction industry determines what is measured as output and clearly, there are different opinions as to what the construction industry includes. Construction industry productivity growth rates might be incorrect due to reported 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. Therefore, alternative approaches are suggested, such as using intermediate outputs. The debate on construction productivity focused on industry level productivity until the end of the 1980s; in the 1990s studies focusing on the firm, project and activity or task levels began to appear. Looking at the different levels reveals that data aggregated to the industry level (national statistics) show lower values for productivity growth, and were surprising to construction practitioners actively involved in the construction process who considered that productivity improvements were their responsibility.

The difficult of measuring changes in output and input qualities applies to other industries such as agriculture and services. Based on the EU KLEMS database, which provides industry level productivity growth rates, the construction industry shows similar productivity growth patterns to business services. These two sectors also have similar problems related to measuring productivity such as heterogeneity of inputs and outputs, and the presence of co-production. In light of these similarities between these industries, theories of productivity from services were analysed to extend the range of construction input and output qualities.

The concept of client productivity, client satisfaction and customer co-production are areas that are well developed in the services sector and offer alternative measures. In the construction industry, customer co-production is not straightforward due to the presence of three co-producers, namely the client, the providers of architectural and engineering services and the contractors. Satisfaction can be included in productivity measures because satisfaction is an indicator of hidden implicit prices for various characteristics of outputs. Multi criteria frameworks are need to capture input and output qualities such as customer satisfaction.

4.2 Paper II – Environmental assessment tools and efficiency in housing and office refurbishment

Considering the aging building stock in Europe and regulatory requirements to decrease energy consumption, it can be forecast that the share of refurbishment projects among the other construction activities will increase. Most existing building certification schemes lack a clear refurbishment focus although refurbishment differs from new construction. Similarly, the early literature on building certification schemes does not go beyond comparing them based on the indicators used; thus, an analysis of existing building certification schemes in the refurbishment context would be useful.

The purpose of this paper is to provide a framework in order to assess strength and weaknesses of environmental assessment tools for housing and office refurbishment projects, taking into account practical aspects, fundamentals of sustainability as well as conflicts between sustainability and efficiency.

Sustainable refurbishment is more complex than sustainability in new construction since in the former, the environmental impacts of waste are more visible. In order to distinguish between these two types of construction activities, the ecologist perspective and its fundamentals needs to be analysed. Conservation and preservation are two common views in the ecologist perspective. The conservationist view is more anthropocentric, meaning that social capital is substitutable and the aim is to achieve intergenerational equity, whereas preservationist view presents a more pessimistic picture and is aimed at maintaining species and wilderness, because social capital is not substitutable, and intergenerational equity is disregarded. Following the preservationist view, issues such as resource use and waste in refurbishment should be highlighted since they are expected to have a bad influence on the nature. However, resource use can be disregarded because it is unlikely that in a refurbishment context, resource use might cause ecological system breakdown.

Another problem related to sustainable refurbishment arises from building's occupants and neighbours. Especially in office refurbishment, staff productivity is decreased due to local disruptions, such as noise and dust, during the process. Moreover, while sustainable refurbishment brings environmental and economic benefits by decreasing energy usage, CO_2 emissions and increasing property prices, it can also result in rent increases, which could influence social sustainability. These complexities should be reflected in building certification schemes.

So far, the usefulness of existing building certification schemes in a refurbishment context has not been compared. Some studies point to interesting limitations in existing building certification schemes: lack of flexibility for adaptation to the regional differences, lack of consideration of costs and ambiguities about the reliability of the schemes.

Based on the above discussion, a list of criteria that includes environmental, economic, social sustainability, and sustainability in general categories, is developed in order to assess building certification schemes. From an environmental sustainability perspective, a building certification scheme should provide sufficient flexibility to enable adaptation of criteria to

local, regional and national differences, and should give higher priority to waste. Efficiency is related to short term productivity, and during the refurbishment process, efficiency decreases. Thus, efficiency is another criterion that should be included in certification schemes. The category of economic sustainability also includes the effort required to obtain certification. In the area of social sustainability, the involvement of occupants can be problematic as well as beneficial. Firstly, adaptation to individual user needs might be more difficult in refurbishment. Secondly, since more parties are involved in refurbishment projects, it is more difficult for stakeholders to understand the scheme - certification schemes should be aimed at facilitating communication between stakeholders. Thirdly, there is less ambiguity of user behaviour in refurbishment projects because the occupants usually are known; therefore this criterion is less important for refurbishment than other construction activities. Finally, in the category of sustainability in general, there are only minor differences between construction activities. Three criteria are suggested: a certification scheme should evaluate both product and process, should have a mix of qualitative and quantitative measures and should be compatible with national building codes, EU directives, and standards.

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

Refurbishment and new construction differ in several ways, and the uncertainties pertaining to the existing buildings and tenants' involvement are two among these differences. The construction industry has been criticised for its low productivity growth rates although one explanation for them is the problems related to measuring productivity, namely the difficulties involved in measuring changes in input and output qualities. Both the aging building stock in Europe and regulatory requirements to decrease energy consumption, highlight the need to develop better alternatives for sustainable refurbishment. However, since refurbishment projects are often triggered by a desire to save energy, more attention is paid to environmental sustainability. Most existing building certification schemes, including the BREEAM Refurbishment Domestic Buildings, the German DGNB scheme, the LEED for New Construction and Major Renovations and Japan's CASBEE for Renovation, have not taken account of the overall sustainability of the refurbishment process. They reflect the fundamentals of sustainability only weakly and they tend to hide conflicts between sustainability and productivity. They mostly lack a clear refurbishment focus, even where there is a special version for refurbishment. Contractor size can be one factor that explains the existence of and need for formal productivity and sustainability policies. Large organisations are expected to adopt formal management control systems, while in smaller firms the organisational culture is absorbed through informal interactions, and personnel control systems are initially informal, but become formalised when firms grow. Also, larger firms tend to plan their environmental practices better than smaller firms.

From the contractors' perspective, and considering the increasing volume of refurbishment projects, it would be useful to have indicators that better reflect the characteristics of building refurbishment. However, before any attempts to develop new indicators for exploitation in future building refurbishment projects, it is crucial to understand the nature of current productivity and sustainability indicators, and how, why and why not these indicators are used

by refurbishment contractors in practice. The aim of this paper is to analyse the use of building refurbishment productivity and sustainability indicators by construction contractors.

The empirical basis of the paper is semi-structured interviews which lasted between 10-25 minutes and were 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 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 through cost recording systems and a few area-based key indicators. Sustainability is still a new concept for refurbishment contractors. SMEs may have sustainability policies, but routines derived from such policies are weak on site. For large contractors, sustainability policies are more developed and are reflected in site routines. However, for SMEs, refurbishment technology choices are often made by the client's designer, and sustainability requirements are included in the contract specifications. Large contractors are usually public companies with stakeholders who expect such routines. Lack of motivation due to absence 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 is worth remembering that simple measures of productivity are easy to apply, but obviously do not capture the complexities of input and output quality. It is an urgent task to find easily applied indicators of economic sustainability at project level. Indicators are needed that make sustainability monitoring more attractive and which clearly present the benefits to be gained from monitoring sustainability.

5 Discussion

This chapter discusses the findings in the appended papers and centres on their relation to the two research questions.

RQ1: How are sustainability and productivity measured by contractors in refurbishment projects?

In economic theory, productivity is basically the ratio of output to input, and in construction site research, productivity often is measured as labour productivity, machinery productivity, materials consumption and actual versus budgeted hours. However, earlier studies in Sweden indicate that site managers' use of the term productivity often refers to costs (Forsberg, 2008; Polesie, 2011). SMEs and large contractors can be expected to show major differences related to monitoring performance: large organisations adopt formal management control systems and tend to plan their environmental practices. Thus, the relation between productivity and sustainability assessment on refurbishment sites is complicated by the absence of actual measurement of output/input ratios in contractor practice. Building certification schemes are a possible inspiration when it comes to sustainability measurement, although they have been criticised for their focus on environmental sustainability and new construction. As already mentioned, BREEAM and LEED are the building certification schemes used most frequently by large Swedish contractors.

The results in Paper III show that the main methods used for monitoring resource are cost recording systems and simple measures such as hours/m^2 and materials/m^2. Simple measures are practical, easy to use and require little data although they cannot capture the complexities of input and output qualities. Customer satisfaction surveys were mentioned and they are useful for capturing one aspect of output quality. Client productivity has obvious effects on contractors' productivity, especially in refurbishment projects where owners are heavily involved. Among large contractors, clients might be better educated and more experienced, and have higher expectations, compared to the clients of SMEs.

According to Walsh et al. (2013) in large service sector firms, resources deployed in improving productivity, and institutional pressure, influence the level of productivity measurement. The interviews confirmed that contractors invest in monitoring resource use until the marginal gains from monitoring productivity equal its marginal costs. Lack of time is a major constraint on monitoring resource use in both SMEs and large contractors; however, Engwall and Jerbrant (2003) note that using the excuse of "lack of time" is usually a symptom of complex resource allocation and might be culturally determined. More constraints were mentioned by large contractors due to the more detailed productivity measures employed, which can be further explained by higher institutional pressure on large contractors.

Sustainability is a new concept for refurbishment contractors. As discussed in paper III, energy savings were not mentioned by SMEs (although energy consumption is a good reason for sustainable refurbishment). The likely reason for is that SME projects are carried out based on detailed designs provided by clients, which specify the thermal insulation to be added, etc. SMEs identified monitoring waste, use of environmentally-friendly materials and

customer satisfaction surveys, but did not immediately associate these activities with sustainability. Large contractors spontaneously referred to environmental and social sustainability, however, they did not use the term “economic sustainability”. The only economic sustainability measure noted during the interviews was “potential energy savings”.

The term ‘customer’ is ambiguous, which affects measurement of customer satisfaction in relation to who is the customer and who should be responding to customer satisfaction surveys. While the benefits of close relations with the client were identified by contractors, refurbishment effects on client productivity were not considered for measurement. To summarise, the focus for refurbishment contractors is clearly environmental and social sustainability, with economic sustainability generally disregarded, at least by site and project managers although top managers might be more concerned with long-term financial aspects.

Sustainability is monitored differently in SMEs and large contractors. Respondents from large contractors identified a wider set of sustainability measures, compared to SMEs. The difference fits the hypothesis that larger firms tend to plan their environmental practices better than smaller firms (Darnall et al., 2010), and that regulatory requirements force larger companies to pay more attention to monitoring sustainability. However, regardless of regulatory requirements, it would be useful to know how large contractors measure sustainability at project level in a way that allows them to link this to their firm level performance.

Building certification schemes were not mentioned by either SMEs or large contractors, although large contractors are officially using BREEAM and LEED to certify their projects. Obviously, building certification schemes do not have a direct influence on the sustainability measurement routines of practitioners working at project level in refurbishment projects. This might be because only a few building certification schemes provide special refurbishment versions which are insufficient and not popular.

Contractors do not develop indicators to cover all aspects of sustainability for various reasons. SME respondents tended not to see any economic benefits from measuring sustainability, and do no more than regulatory requirements demand. Large contractors said that clients did not demand it, there was thus no competitive advantage and there were difficulties related to seeing where measurement results could be applied. Thus, the main reason why firms do not measure sustainability, regardless of firm size, is lack of perception of clear economic benefits.

RQ2: Which principles could be followed when reconciling sustainability and productivity in a refurbishment context?

Productivity is defined here as a traditionally measured ratio of output to input depending on market prices, and is usually presented in the form of labour productivity, which is less costly to measure but also less informative (Sudit, 1995), and suffers from heterogeneity of labour inputs (Schreyer, 2001). Chau and Walker (1988) suggest multi-factor productivity, however

the problem of measuring a variety of input qualities and quality changes is even greater in relation to estimating multifactor productivity.

Dacy (1965), in his pioneering article, attempts to explain low productivity growth in the construction industry through the notions of: shifts in construction product mix, geographical distribution, increase in construction firm size in contract construction, introduction of new techniques, decline in average age of construction workers, and increase in capital per worker. As claimed in Paper I, low growth rates in the construction industry cannot be explained by productivity determinants that operate only in the short or medium term. Decline in the average age of the workforce is necessarily finite. Looking at the level of analysis, debate on construction productivity was dominated up to the end of the 1980s by economists, and was focused on industry level productivity; obviously, economists did not go beyond short or medium term explanations by analysing industry level statistics.

In Paper I, the EU KLEMS database was used to reveal industries that present similar productivity growth trends to the construction industry. In addition to sharing similar patterns of productivity growth, the relation between business services and the construction industry is discussed in Paper I in the context of seven problems related to the measurement of aggregate productivity. Clearly, problems related to measuring quality change when analysing productivity growth are shared with the services sector (Griliches, 1992).

Paper I suggests extending the range of output and input qualities and multi criteria frameworks. Client productivity is one such quality that has been used in the context of management consulting services. Involving client productivity as an input is discussed, but then output as a result of the services bought, is difficult to define because such effects do not emerge instantly and ideally should be measured over a period of time. Customer satisfaction surveys are useful for capturing one aspect of output quality. There is a clear link between client satisfaction and client productivity. However, the types of construction contract, such as design-build and design-bid-build, include three-party relationships among construction clients, providers of architectural and engineering services, and construction contractors. In refurbishment projects, tenants are usually involved as well. Therefore, it is not a simple case of customer co-production; there is the presence of three or, in the refurbishment case, four co-producers which creates extra challenges for productivity measurement. Finally, time precision as well as cost and quality precision, which are important characteristics of service process quality, need to be analysed in the construction industry since clients might pay extra for such qualities.

Using building certification schemes is one way of evaluating sustainable performance. Most existing building certification schemes, including the BREEAM Refurbishment Domestic Buildings, the German DGNB scheme, the LEED for New Construction and Major Renovations and Japan’s CASBEE for Renovation, generally lack a clear refurbishment focus, even where there is a special version for refurbishment. That might be because most building certification schemes aim for an artificial, new building that matches a set of standards. The origins of current certification schemes are new construction although some of them have added a refurbishment version derived from the original version.

The environmental impacts of waste are more visible in refurbishment, and require more attention compared to new construction. Analysing the ecologist perspective in Passmore (1980) enables a distinction between refurbishment and new construction. The ecologist perspective proposes two views: conservationist and preservationist. As pointed out earlier, in the preservationist view, waste should be highlighted as an important indicator of sustainable refurbishment.

In developing sustainability indicators, local and regional differences should be taken into account. Todd and Geissler (1999) focus on regional differences such as land or water being scarce resources. More interesting, they note a dilemma related to whether a building certification scheme should allow changes for regional differences or set a universal standard. They propose partial flexibility which gives enough room to modify the scheme for a specific region while retaining criteria with international impacts intact.

Existing certification schemes focus on environmental sustainability (Berardi, 2012). However, two other aspects of sustainability should be included in an overall sustainability focus. The conflict between economic sustainability and efficiency is obvious in refurbishment since efficiency reflects short term productivity of the refurbishment process, while economic sustainability is long term productivity.

One further way of reconciling productivity and sustainability is based on the more complicated relations between productivity and environmental and social sustainability. A higher level of environmental and social performance increases customer satisfaction and satisfied customers are assumed to be willing to pay more. Their willingness-to-pay is probably increased in the presence of well-known building assessment schemes and standards to corporate social responsibility (CSR). Higher demand, ceteris paribus, raises market prices. Increased market prices reflected as output value increase productivity.

As argued in Paper II, there might be conflicts between aspects of sustainability in refurbishment projects. For instance, in energy efficiency refurbishment (retrofit) projects, the goal is to decrease energy use and, thus, provide positive environmental results. It is well known that refurbishment increases property values and (usually) rents, which produces positive economic results for the property owner, but could be harmful to social sustainability. Also, while sustainable refurbishment is aimed at providing long term, global, positive environmental effects by decreasing energy usage and CO_2 emissions, there are short term, local, negative environmental effects, such as dust and noise, that cannot be disregarded.

Stakeholders, particularly those present in the building during refurbishment, make sustainability measurement more complicated. Considering that one of the aims of building certification schemes is to communicate with customers (Crawley and Aho, 1999), such schemes are expected to be easily understood by stakeholders.

6 Conclusion

The current methods of measuring productivity in the construction industry are limited to simple area-based methods and labour productivity, which do not capture the changes in input and output qualities. 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, for example, client productivity and customer satisfaction surveys, could be useful.

Sustainability is often measured using building certification schemes. However, most existing building certification schemes have not taken account of the overall sustainability of the refurbishment process. They reflect the fundamentals of sustainability very poorly, and they tend to hide conflicts between sustainability and productivity. They mostly lack a clear refurbishment focus, even in schemes that are supposed to include refurbishment.

Sustainability is a new concept for refurbishment contractors compared to productivity. Refurbishment contractors use simple measures of hours and materials per m^2 and cost control systems for measuring productivity. SMEs' sustainability measurement practices are focused on environmental sustainability while large contractors also acknowledged economic and social sustainability. Lack of time is a common excuse for not measuring productivity sufficiently although it might be a symptom of complex resource allocation. SMEs pay little attention to sustainability measurement because they do not see it providing economic benefits, while absence of client demand is the explanation given by large contractors. It is an urgent task to find easily applied indicators of economic sustainability at project level. Considering the explanations identified here for weak sustainability monitoring on sites, indicators are needed that make sustainability monitoring more attractive and which present clear benefits from monitoring sustainability.

7 Future research

As presented in this thesis, literature reviews dominated the project during the licentiate period. However, some empirical data were collected and remainder of the project will be based mainly on empirical data.

The overall project addresses three research questions; the present thesis is based on two of them. The last research question, “which practically useful performance measures are consistent with principles of sustainability and productivity?” is related to future research plans. Future research could develop new measures that recognize the potential conflicts between sustainability and productivity, taking account of the practical issues related to monitoring performance.

Two of the papers included in this thesis are aimed at developing a framework and indicators in order to evaluate productivity and sustainability in refurbishment projects. These papers will be developed further by analysing four building certification schemes that include refurbishment, and assessing how useful they are from a productivity and sustainability perspective. The empirical basis of this paper will be the analysis of four building certification schemes that cover a range of building types: BREEAM Refurbishment Domestic Buildings, the German DGNB scheme, LEED for New Construction and Major Renovations and Miljöbyggnad (Sweden Green Building Council).

Refurbishment is not pure production of goods. Considering the service characteristics of refurbishment and the three-party relationship of construction clients, providers of architectural and engineering services and, construction contractors, research on co-production in refurbishment projects would be beneficial. Issues such as the client-customer dilemma could be addressed. It would be interesting also to analyse strategic partnering of contractors and public clients, and who has responsibility for measuring productivity and sustainability.

The few empirical data collected for this thesis are focused on the site level. Large contractors’ hierarchies consist of site level, regional level and top management level. Sustainability is clearly an important aspect in large contractor organisations; however their routines of sustainability and productivity monitoring on sites are weak or lack coordination. Sustainability policies are possibly stronger in the upper levels of contractor organisations compared to the on site level, which might be due to lack of communication and collaboration with site managers. Internally, environmental experts, project estimators and planners influence site managers and their site routines for productivity and sustainability monitoring. External factors that influence sustainability and productivity monitoring on site, are client skills, the financial community and environmental certification schemes. Therefore, the direction of research to extend this thesis should focus on analysing internal and external effects by starting with regional levels of the large contractors. The staff working at the regional level, and those who are in touch with site managers, will be interviewed. The interviews should provide a better understanding of sustainability and productivity among regional staff, what they want to be monitored on site, and why, what the logic is behind those

measures, how they inform site managers and how satisfied they are with site managers in terms of monitoring productivity and sustainability.

The initial data collected for the present thesis were useful for developing the hypotheses. However, in order to test these and generalise the results, questionnaire surveys are planned to be sent to site managers, project managers and contractors' staff working at the regional level. Separate surveys for site and regional levels should allow analysis of different perspectives.

Finally, future plans include a study of information technology (IT) support systems for construction sites. The study will examine existing IT support for the construction sites and identify requirements for an IT support system appropriate for refurbishment projects. Such an IT support system would be very useful, especially for SMEs which have fewer opportunities and resources to develop their own IT support systems.

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