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Rikard Nilsson

LICENTIATE DISSERTATION
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Faculty opponent
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Abstract

Many policy targets have been developed with the aim of reaching a more sustainable development; more specifically, the studied policies target energy use and urban growth. For example, by 2050 the aim is that the European Union will have reduced its greenhouse emissions by 90%. Examples of policy targets regarding urban growth can be found in many of the larger cities, as they have developed plans for densification so that the population can continue to grow without expanding the city borders. Reaching these targets might be challenging as the human population is predicted to grow and more people are moving to cities.

Even though, there are benefits such as reducing energy use and extending the lifespan of existing buildings, many claim that energy-efficient renovations are complicated and expensive. Moreover, the densification process is lengthy and finding the right balance is challenging when many stakeholders are involved. Many citizens are negative towards densification projects, as such developments often occupy recreational space. Since both energy-efficient renovation and densification projects are challenging to implement, other solutions have to be found. The vertical extension of buildings can be considered a mix of both energy-efficient renovation and densification and therefore has similar benefits and challenges; however, there are differences. By extending a building vertically no recreational space is occupied and, by selling the added apartments, an extension can pay for the refurbishment of the existing building.

In this research, the impacts on sustainability of extending buildings vertically and success factors for the implementation of vertical extension of buildings have been studied. Three studies were undertaken, the aim of each study was to highlight different perspectives of the vertical extension of buildings. The results of the first study show that the vertical extension of buildings can act as an enabler for energy-efficient renovation and that a low-energy plus the vertical extension renovation concept can reduce energy use by as much as 60%. In the second study the authors claim that stakeholder participation can lead to more sustainable densification projects; however, currently, it is up to the individual proponents of participation to implement such a process. The results from the third study show that extending a building vertically is a complicated process. A development process was proposed in order to simplify implementation.

Key words: sustainability, densification, energy-efficiency renovation, urban development, stakeholder

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When I started my PhD studies I felt that I lacked sufficient language skills and knowledge about the subject. It was not until recently that I realised what was going to be my approach and my contribution; even now, I still wonder where my future work will take me. Every day is a new adventure and I am learning so much about both research and myself. Compared to other PhD students I have met, I have had a lot of influence over my work, which has been very rewarding.

I would like to thank my supervisor Anne Landin and co-supervisor Stefan Olander for taking me in and guiding me through this journey. I want to express my gratitude to Brian Atkin for reviewing all of my work, this have greatly developed my writing and research. I am very grateful to all the colleges from the division of Construction Management at Lund University, without their support I might have struggled; the hospitality and the willingness to share knowledge that we have at the division has been key to my development. I also want to thank Åke Blomsterberg from the division of Energy and Building Design for great collaboration. Finally, I would like to thank my lovely fiancée Marie for her support.

Lund, April 2017

Rikard Nilsson

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Many policy targets have been developed with the aim of reaching a more sustainable development; more specifically, the studied policies target energy use and urban growth. For example, by 2050 the aim is that the European Union will have reduced its greenhouse emissions by 90%. Examples of policy targets regarding urban growth can be found in many of the larger cities, as they have developed plans for densification so that the population can continue to grow without expanding the city borders. Reaching these targets might be challenging as the human population is predicted to grow and more people are moving to cities.

Even though, there are benefits such as reducing energy use and extending the lifespan of existing buildings, many claim that energy-efficient renovations are complicated and expensive. Moreover, the densification process is lengthy and finding the right balance is challenging when many stakeholders are involved. Many citizens are negative towards densification projects, as such developments often occupy recreational space. Since both energy-efficient renovation and densification projects are challenging to implement, other solutions have to be found. The vertical extension of buildings can be considered a mix of both energy-efficient renovation and densification and therefore has similar benefits and challenges; however, there are differences. By extending a building vertically no recreational space is occupied and, by selling the added apartments, an extension can pay for the refurbishment of the existing building.

In this research, the impacts on sustainability of extending buildings vertically and success factors for the implementation of vertical extension of buildings have been studied. Three studies were undertaken, the aim of each study was to highlight different perspectives of the vertical extension of buildings. The results of the first study show that the vertical extension of buildings can act as an enabler for energy-efficient renovation and that a low-energy plus the vertical extension renovation concept can reduce energy use by as much as 60%. In the second study the authors claim that stakeholder participation can lead to more sustainable densification projects; however, currently, it is up to the individual proponents of participation to implement such a process. The results from the third study show that extending a building vertically is a complicated process. A development process was proposed in order to simplify implementation.

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1.Introduction

1.1 Background

Today, the construction industry is faced with a number of challenges, many of which is related to the growing urban population and climate change. According to the United Nations' World Urbanization Trends (2015a) and World Population Prospects (2015b) reports, the world population is projected to increase about 50% within this century and the urban population, as percent of total population, is projected to increase by 12% over the coming 50 years. Many cities are therefore experiencing rapid population growth and will continue to do so for the foreseeable future. According to the Swedish National Board of Housing, Building and Planning [Boverket] (2012), there is a housing shortage of somewhere between 90 000 and 150 000 homes in Sweden. Moreover, reducing the risk related to rising sea levels, an effect of global warming, will require migration, mitigation and settlement modification (McGranahan, et al. 2007). The underlying concept of sustainable development is that, today, we use resources in excess of those being naturally generated. Whilst this benefits us today, it will limit available resources for future generations. In order to reach a more sustainable development, solutions for these challenges have to be found. A solution which could increase population density and reduce energy use is vertical extension of buildings.

Reducing human impact on the environment by reducing the use of fossil fuels has been the focus of many policy targets. The European Commission (2011) initiated the "Energy roadmap 2050" where one of the targets is to reduce greenhouse gas emissions within the European Union between 80% and 95% by 2050. In response, Sweden is striving for zero net emissions by 2050 (Miljö- och energidepartementet, 2014). Reaching these targets will require both an increase in renewable energy production and more efficient use of that energy. One of the five 2020 targets set by the EU is *Climate change and energy sustainability* (European Commission, 2010), which consists of three targets: greenhouse gas emissions 20% lower than 1990, 20% of energy from renewables and 20% increase in energy efficiency. According to the European Commission (2015), it seems that these targets can be meet; however, there is still a lot of work left to be done regarding the increase in energy efficiency. By 2013, primary energy efficiency had only increased by 11.9%. In a country report (European Commission, 2016), Sweden was reported as having met the targets for reduced greenhouse gas emissions and energy from renewables; but, just as the EU in general, Sweden still needs to increase its primary energy efficiency. In order to meet the target, Sweden would have to reduce its primary energy at a greater rate between 2014 and 2020 than was achieved between 2005 and 2013. Since a large portion of national energy consumption comes from the building stock, the Swedish building regulations have been continuously revised in order to reduce energy consumption (Boverket, 2011; 2015).

In order to cope with the population growth and the housing shortage, urban planners and developers will have to find solutions that involve both densification and an expansion of the built environment. However, expanding city borders leads to urban sprawl, more traffic and also less land for agriculture and wildlife. Therefore, densification might seem a better option as it can bring more services and more efficient infrastructure. Even so, densification is faced with challenges, which a rural or suburban development is not, such as overpopulation, pollution and limiting infrastructure. No matter the consequences, there is a growing demand for housing and services in city centres and, for better or for worse, this demand has changed and will continue to change our urban environment. Since habitat loss and habitat degradation are the largest threats to wildlife and as many countries still need to increase their energy efficiency, a solution to both problems would be an interesting subject to study. Densification could be one such solution, since it increases the amount of housing within a city's boundary and can raise the operational efficiency of the infrastructure within that city. Boverket (2014) has developed a vision of Sweden in 2025; in this vision, one of the ways to achieve a more sustainable living environment in and around cities is through densification. There are also plans for densification in whole regions such as in Scania (WSP, 2013). Each of the three biggest cities in Sweden – Stockholm, Gothenburg and Malmö – have developed individual plans for densifying the built environment (Regionplanekontoret, 2009; Göteborgs Stad, 2014; Malmö stad, 2010).

These documents present a clear message: there is a governmental, regional and municipal political willingness to reduce energy use of existing buildings and densify the cities in Sweden. By extending a building vertically, energy use is affected in two different ways: the extension has to follow the building code; therefore, the new roof will be more efficient than the old roof. During extension, there might be opportunities for energy-efficient renovation of the existing building. Extending a building vertically increases the number of homes and services without extending the urban footprint, thus densifying the city.

1.2 Research questions

The introduction highlighted that vertical extension of buildings was linked to sustainability; however, no research has been undertaken that directly links vertical extension of buildings to sustainability. Moreover, little research has been undertaken that explores and explains the success factors for the implementation of the vertical extension of buildings. Therefore, the following research questions were formulated.

1. How can the vertical extension of buildings impact sustainability?
2. Which are the main success factors for extending buildings vertically?

The first research question was formulated with the aspects of sustainability in mind, since the effects and consequences of extending buildings vertically can be divided into environmental, financial and social implications. The second research question is focused on finding and explaining the key success factors for the implementation of vertical extension of buildings and presenting the opportunities and challenges during implementation.

1.3 Aim and objectives of the research

The primary aim was to study the links between sustainability and the vertical extension of buildings. A secondary aim of the research has been to study the vertical extension of buildings, its effects and consequences in the urban environment, as well as its implementation.

Research objectives

In order to reach this aim and to answer the research questions, several objectives were formulated. The objectives acted as guidelines during the research.

1. Identify and engage with stakeholders involved in extending buildings vertically.
2. Identify and examine instances where buildings have been extended vertically.
3. Identify and examine related research fields.
4. Propose a development process for the implementation of a vertical extension project.

In order to establish an in-depth understanding of a phenomenon, several facets and perspectives of the phenomenon have to be studied. In this dissertation, those facets are the three aspects of sustainability (environmental, economic and social) and the perspectives are those of key stakeholders such as housing companies, policy makers, city planners, developers and building contractors (see figure 1.1). Linking the research to the concept of sustainability offers other researchers and practitioners additional insights. By showing both private and societal benefits and the consequences of extending buildings vertically, the researcher hopes to attract more attention to the research.

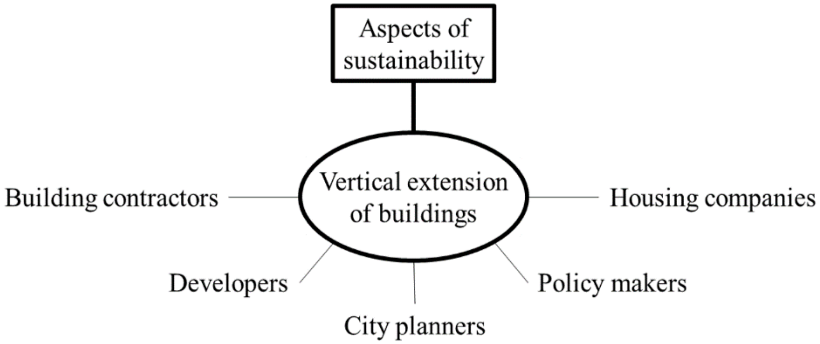


Figure 1.1 Different perspectives of the vertical extension of buildings

1.4 Limitations

The research and, therefore, this dissertation is limited to the links between vertical extension of buildings and the three aspects of sustainability and the perspectives of key stakeholders. The author's standing is that any construction must, to some extent, consider sustainability. Sustainability does, therefore, permeate the whole dissertation.

Whilst study 1 focuses heavily on the renovation of multifamily buildings, they can both be linked to environmental and economic sustainability. Study 2 focuses on stakeholder participation in densification projects, which can be linked to social sustainability. Study 3 on the other hand is not focused on any particular aspect of sustainability, but is instead focused on the practical implementation of the vertical extension of buildings. Procurement and onsite construction phases of the vertical extension projects was not investigated; instead, more effort has been put into the initiation and planning phases.

1.5 Contributions

Scientific papers

I. Renovation of a Multi-family Building in Sweden – Analyses of Energy Savings, LCC, LCA and Co-benefits
Presented at the 12th REHVA World Congress CLIMA 2016, 22-25 May, Aalborg, Denmark
Authors: Åke Blomsterberg and Rikard Nilsson

II. Vertical Extension of Buildings as an Enabler of Energy Renovation
Presented at the 12th REHVA World Congress CLIMA 2016, 22-25 May, Aalborg, Denmark
Authors: Rikard Nilsson, Åke Blomsterberg and Anne Landin

III. An exploratory study of the practice of stakeholder participation in densification projects
Presented at the 20th CIB World Building Congress 2016, 30 May to 3 June, Tampere, Finland
Authors: Carlos Matinez-Avila, Rikard Nilsson, Stefan Olander and Anne Landin

IV. A development process for extending buildings vertically – Based on a multiple case study of four buildings
Manuscript to be submitted 2017
Author: Rikard Nilsson

Distribution of work

Tabel 1.1 The distribution of work for the papers

Paper	Distribution of work
Paper I	Nilsson contributed in the empirical study and the review of the paper while Blomsterberg wrote most of the paper.
Paper II	Nilsson wrote most of the paper; Blomsterberg contributed to the empirical study and the review of the paper, and Landin supervised the work.
Paper III	Nilsson contributed in the empirical study and wrote the introduction and the densification theory of the paper. Martinez-Avila contributed to the empirical study and drafted the stakeholder theory and analysis in the paper. Olander rewrote the individual sections into the final paper and Landin contributed to the work on densification in Sweden as well as supervising the work.
Paper IV	Nilsson is sole author.

Links between the research questions and the papers

Tabel 1.2 The links between the research questions and the papers

Research question	Paper
1. How can the vertical extension of buildings impact sustainability?	Paper I, Paper II, Paper III
2. Which are the main success factors for extending buildings vertically?	Paper II, Paper IV

1.6 Structure of the dissertation

This dissertation consist of seven chapters and each chapter highlights a specific topic related to the research process. The first chapter has presented the background to the research, the research questions, the aim and objectives of the research, and the contributions.

Chapter two presents the epistemological ideals and the two methods of reasoning used in the research. Moreover, the research process and the method used for data gathering, namely case study research, are presented.

Chapter three presents the theoretical links between sustainability and the vertical extension of buildings. In this chapter, sustainability and its three aspects are reviewed, then measures for reaching a more sustainable environment are reviewed. The two measures studied are densification and energy-efficient renovation: vertical extension of buildings is considered a sub-measure to the other two measures.

In chapter four, the three studies, which this research is based upon, are described. All three studies were case studies. Studies 1 and 3 is directly linked to the vertical extension of buildings, while study 2 is linked to social sustainability and densification.

Chapter five presents the findings and the analysis of the three studies. The findings highlight how vertical extension of buildings can impact sustainability. In the analyses the findings are divided into the three aspects of sustainability, which are then built upon.

Chapter six consists of a discussion of the research as a whole. The author highlights some of the limitations of the research. The purpose of the discussion is for the author to reflect on the research and find opportunities for improvement.

Chapter seven presents the conclusions of the research. The purpose of the conclusions are to answer the research questions and thereby finalise the dissertation. Proposed future research is also presented in chapter seven and provides the reader with insights into what is to come in the doctoral dissertation.

2.Research methodology

In this chapter, three topics related to the research methodology are presented. First, the methods of reasoning used and the epistemological standing of the author are presented. The goal of the research process is to highlight how the research has been planned and executed. Finally, the methods for data gathering which have been used are described.

2.1 Epistemology

2.1.1 The Socratic approach

Socrates had three perspectives that characterised his attitude towards knowledge. These are the foundation of philosophy and, therefore, research. They are conceptual orderliness, knowledge stability and fallibility (Persson and Sahlin, 2013).

- Conceptual orderliness. We should aim for clarity and try to avoid ambiguity and obscurity. We should think about the meaning of the words that we use and avoid using those that have many or different meanings. We should also avoid vagueness in our research.
- Knowledge stability. We should be aware of what we know (the known), what we know that we do not know (the unknown) and what we do not know that we do not know (the unknown unknown).
- Fallibility. We should be aware that we all are fallible; our beliefs and biases do to some extent affect our research. Finally, we should be aware that just because something has happened before does not mean that it will happen again.

The Socratic approach requires three preconditions: (1) that we believe that things can either be true or false; (2) that we believe that everything follows logical consequence; and (3) that we believe in a world irrespective of us.

2.1.2 Reasoning

There are three fundamentally different methods for reason in research: deductive, inductive and abductive, each method serves a different purpose and depending on the research one method might be preferred over the others (Persson and Sahlin, 2013). Deductive reasoning consists of three steps, formulating a hypothesis, testing the hypothesis and drawing conclusions. One requirement for using the deductive method is that the formulated hypothesis is testable and that similar tests can be replicated by others. Moreover, if a test yields positive results it does not mean that that the hypothesis is true, instead the test only supports the hypothesis. No amount of testing proves anything; they only further strengthen the hypothesis. Since no testable hypotheses were found, deductive reasoning has not been applied in this research; therefore, inductive and abductive reasoning were chosen instead.

Inductive reasoning

Inductive reasoning, sometimes called bottom-up reasoning, expects the researcher to make conclusions based on observations, without any guesses or hypotheses (Persson and Sahlin, 2013). Inductive reasoning has two characteristics.

1. The conclusion is comprised of more than the premises.
2. The observations have to be many and varied.

Since inductive reasoning is based on earlier observations, the conclusion can never be certain; instead, it is only probable that the conclusion holds true. The more observations that are made, the more probable the conclusion is; however, an inductive conclusion does not prove anything. The number and variety of observations should be enough to find probable conclusions. However, in practice, it is challenging to make enough observations without ample resources. This is especially true in the construction industry since construction projects are temporary, unique and often large in scale. A small number of observations limits the conclusions that can be made. Another issue is that the lack of deeper knowledge, regarding a project under investigation, might lead to too general and lacklustre conclusions.

Abductive reasoning

Abductive reasoning attempts to find explanations given available data. The goal is to understand the phenomenon and why it happened; the goal is not to deduce or prove anything (Persson and Sahlin, 2013). Therefore, an abductive researcher might not be interested in what is true or not, but rather what best explains the phenomenon. Any explanation formulated has to be logically compatible with available data. Among the explanations there are usually many that could be described as reasonable explanations, but are not necessarily the truth. There are two aspects to an explanation (Lipton, 2004):

1. likeliness
2. loveliness

The likeliness of an explanation is the likelihood that the explanation is true. Generally, a simpler explanation is more likely to be true than one that is more complicated. An overly-simplified explanation might, however, lack value even though it could be true. The loveliness of an explanation is the potential understanding we can get from it. Although, an unlikely but lovely explanation might be also lack value as it is probably not true. Likeliness and loveliness are therefore both linked, since finding an explanation that is both likely and lovely will generate most value.

2.1.3 The author’s epistemological standing

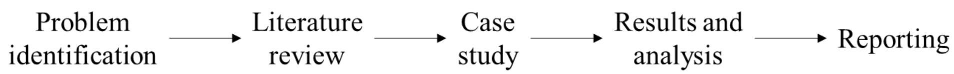
The author recognises the Socratic perspective as representing ideals or values, something which every researcher should strive for, but can never truly achieve. An issue regarding conceptual orderliness is that, as time passes, language change and research presents new findings which alters our understanding of the world around us; therefore, what is considered clear today might be unclear tomorrow. Moreover, even though the aim of a definition is to bring clarity to a term, a definition also introduces other terms which in turn have to be defined, making it difficult to clarify anything fully.

Another issue with the Socratic approach is that one of the preconditions requires a belief that things can be true; however, according to both abductive and inductive reasoning whether something is true or not is not that important. Instead, it is the likelihood that an explanation or conclusion is true which is of importance. Abductive and inductive thinkers do not believe in absolute truths; something can be likely to happen in a certain situation, but it is never guaranteed to happen. According to a Kantian or postmodern world view, we can only experience the world around us through our senses (Pardi, 2015); thus, there is no way to tell if there is a *real* world out there or just our minds playing tricks with us. Therefore, it follows that we cannot know any absolute truths, since we do not know anything about the *real* world; instead we should focus on our experiences and what they tell us. If we can accept the fact that we will never know any absolute truths or the true reality, we can trust our experiences and senses to interpret a phenomenal world with which we can interact.

If we can interact with the phenomenal world, we can also create theories and models of it. If others experience similar results using our theory or model, we have found an agreement. An agreement is not truth, since it can be falsified and, thus, rejected. A theory or model gains strength the more people agree with its validity. This epistemological approach is similar to the positivistic philosophy approach. According to Molander (1988), a positivist is a researcher who uses sensory experience and observations to derive information and through logical reasoning creates knowledge. A positivist rejects pseudoscience and metaphysics as they are not measureable or testable and therefore not worth studying. Truths can only be found in mathematics and logical reasoning, not in the empirical reality. Positivism is a modern take on the Socratic approach, as the three Socratic perspectives can still be found in the foundation of positivism (Persson and Sahlin, 2013). The Socratic approach lets us communicate our theories with other researchers, by providing us with a common framework of ideals on which we can base our research.

2.2 Research process

The research process, see figure 2.1, used for the studies in this research consisted of five steps: problem identification; literature review; case study; results and analysis; and reporting. In the first step a problem is identified. How a problem is identified might vary, a problem can be identified during a literature search, meetings, interviews or presented by other researchers. The aim of the literature review is to define the problem and find information surrounding the problem. The third step is to perform a study of the problem in its real-life context. The results are then analysed and conclusions are drawn. Finally, the study is reported on in a paper, so that others might learn from the study.



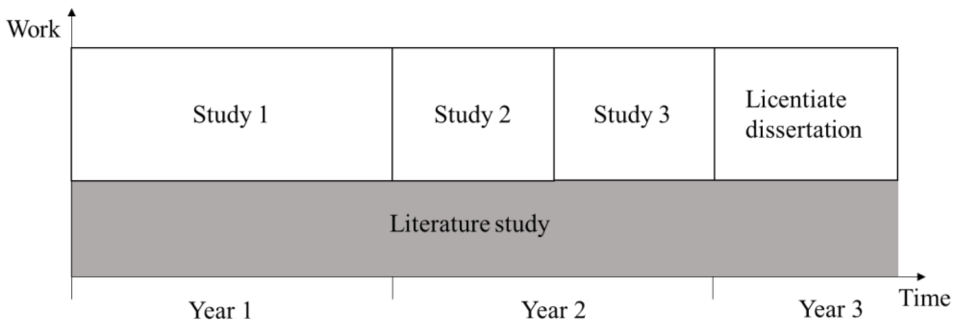
Figur 2.1 The research process.

The research comprises three studies, study 1, study 2 and study 3, see table 2.1. The first was a case study of a multifamily building, which underwent a large-scale renovation. Methods used for data gathering were document analysis, site visits, computer-based simulations and interviews. The second study was a case study using a semi-structured interview series regarding the current practice of stakeholder participation in densification projects. Ten interviews were performed with industry actors. The third study was a multiple case study of four buildings examining the development process associated with the vertical extension of buildings. Methods used for data gathering were mainly interviews but also document analysis and site visits.

Table 2.1 The three studies conducted as part of the research.

	Study 1	**Study 2**	**Study 3**
Research strategy	Abductive	Inductive	Inductive and Abductive
Qualitative or Quantitative	Qualitative	Qualitative	Qualitative
Type of study	Case study	Case study	Multiple case study
Data gathering methods	Document analysis, site visits, computer-based simulations, and interviews.	Interviews.	Interviews, document analysis, and site visits.
Papers	Paper I and Paper II	Paper III	Paper IV

As seen in table 2.1, study 1 was reported in paper I and II, study 2 was reported in paper III and study 3 was reported in paper IV. The studies are described in chapter 4, the findings can be found in chapter 5 and the full-length papers can be found in the appendix. Figure 2.2 shows when the studies were conducted and approximately how much time was spent on each of them.



Figur 2.2 The workload during the research.

2.3 Data collection

2.3.1 Qualitative and quantitative studies

Qualitative and quantitative studies are the two main types for data gathering (Holme and Solvang, 1997). The aim of a qualitative study is to get a better understanding and a more holistic picture of a phenomenon. The results of a qualitative study cannot always be illustrated in numbers, more usually the results are presented as an explanatory text. On the other hand, the aim of a quantitative study is to strengthen or undermine theories or arguments using statistical data. Quantitative studies are characterised by statistical measurements and as the name suggests relies heavily on the amounts of data gathered. Moreover, qualitative studies usually leave room for the researcher to interpret the results, which is both a strength and a weakness. The strength lies in finding underlying data, facts, other relevant research fields or phenomenon which can be used to better explain the studied phenomenon. As seen in table 2.1, all studies made during this research have been qualitative, since the aim has been to explain and understand vertical extension of buildings.

2.3.2 Case study research

In this research qualitative studies have been the main type of study for data gathering, more specifically case study research have been used. A case study is the study of a phenomenon in its real-life context (Yin, 2014). Rather than studying a phenomenon in isolation and separate from its surrounding contexts; a case study also takes into account the surrounding context. A detailed study of a single case can provide in-depth understanding of a phenomenon and the context surrounding that specific case. On the other hand, a multiple case study can provide comparisons between cases and contexts where a phenomenon exists. Whether a detailed case study is better than multiple case studies, or the reverse, depends on the phenomenon, available data and the research question(s). A case study can both be qualitative and quantitative depending on available data and the number of cases studied. Case studies can also be used to falsify hypotheses and theories, since they provide in-depth understanding, and indicate the limitations governing where and how a hypothesis or theory might apply.

A case study was chosen for study 1 for two reasons. First, in order to make detailed comparisons between energy-efficient renovations of the participating countries, a case study was necessary. Second, large-scale energy-efficient renovations are rare and data can be difficult to gather; therefore, one should seize the opportunity when presented. Even though study 2 only consists of interviews, it can be argued to be a case study since, it is a study of a phenomenon in a real-life context and the interviewees were handpicked. In study 3, a multiple case study was chosen since the focus was on the comparison between different cases and so less detail was necessary, compared to the detail level of study 1.

Interviews

An interview is a useful tool for researchers who are exploring a new field, as it offers a more flexible approach than some other means of data gathering (Alvesson, 2011). For example, controlled experiments offer little flexibility regarding the planning and execution of the said experiment; if some aspects have been missed or are not fully understood, it is likely that the experiment will fail. Interviews can therefore be considered more flexible, since improvements to the interview guide and the execution of an interview series can be done during the execution. For example, during an interview the interviewee can present an interesting opinion, which was new information to the interviewer. The interviewer can then change the interview guide in order to see if other interviewees have the same or a different opinion. However, interviews are also flexible in the sense that it is up to the interviewer to interpret the results, which can lead to criticism and questioning the legitimacy of the study. Interviews are considered a qualitative research method since the goal of an interview is to learn from the interviewees' experiences rather than to test a hypothesis or theory. An interview is an interactive method, allowing both the interviewer and the interviewee to ask questions, seek clarification and learn from the interaction.

There are three types of interview: structured, unstructured and semi-structured interviews. The goal of structured interviews is for the interviewer to find answers to his or her questions; usually, these questions are thought through, planned and written down before the interview. In an unstructured interview, the goal is instead for the interviewer to allow the interviewee to share his or her experience and knowledge regarding a specific topic. Semi-structured interviews are partly structured and partly unstructured, thus granting the interviewer the benefits of both so long as the interview is properly designed.

Data-driven coding of interviews allows the researcher to find patterns among individual interviews and from them they can derive conclusions (Kvale and Brinkmann, 2009). Data-driven coding is a bottom-up approach where keywords are highlighted in each transcribed interview and then compared to keywords from other interviews. Several keywords can then form categories and several categories can then form themes. Using this bottom-up 'pyramid' the researcher can then explain interesting themes and refer to them when writing up and presenting the findings.

In study 2, interviews were used since that study was focused on explaining the current practice of stakeholder participation in densification projects. Interviews allowed for direct and flexible interaction with practitioners on this specific topic. In study 2, data-driven coding was applied and so the bottom-up pyramid was structured in four steps: transcripts (bottom), codes (lower middle), categories (higher middle) and themes (top) (see figure 2.3).

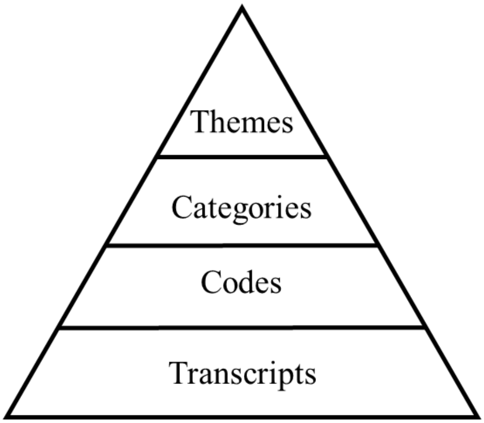


Figure 2.3 The pyramid structure of the results from study 2.

Computer-based simulations

The analysis of the findings in study 1 was conducted using computer-based simulations of energy use, lifecycle impact analysis and lifecycle costs. There are three aspects to simulation that need to be considered in every analysis. First, finding software that has been validated is of key importance. Not all validated software can of course be used; however, it is necessary for the researcher to be aware of the underlying methodology. Another aspect of simulation is input, since a realistic simulation requires precise input data. If there are inaccuracies in both the software and the input data, the output is going to be adversely affected. Finally, a simulation is based on earlier events and not on what actually will happen. It is impossible to predict with accuracy what a building will experience during its many years of operation. Nonetheless, an educated guess, a prognosis, can be made.

Energy use was simulated using *VIP-Energy* (StruSoft AB, 2016a). *VIP-Energy* is software which calculates the energy use of buildings with respect to heating, climate, ventilation and user behaviour. The software has been validated against both ASHRAE 140-2007 and EN 15265-2007. Simulations of energy produced by photovoltaic panels have been compared between *VIP-Energy* and *PVSYST* (Strusoft AB, 2016b).

Lifecycle impact analysis, covering total primary energy, non-renewable primary energy, carbon emissions, was simulated using *Eco-Bat* (Eco-Bat, 2016b). Eco-Bat is software which can be used in the conception phase to analyse the environmental impact of a project or concept. More than 140 materials and six categories of energy consumption have taken into account. *Eco-Bat* software is compliant with ISO 14040:2006, SIA 2032:2010 and Minergie ECO standards (Eco-Bat, 2016a).

Lifecycle costing was simulated using an *Excel* spreadsheet which complied with the IEA EBC Annex 56 methodology (Ott et al., 2014).

Document analysis

Important events are often documented, and like a photo, it is a snapshot in time of an event. Therefore, documents can provide the researcher with data and information regarding an event. Writing is tool for communication and storing knowledge; even though interviewees can describe an event, documents can be used to, in better detail, describe and visualise an event. Therefore, depending on the study, documents can be a more appropriate means of data gathering then interviews. According to Fellows and Liu (2008) documents cannot be regarded as “independent facts” since every document have been shaped with a number of subjective aspects. A document is a reflection of its writer since it is always affected by the writer’s experience of the event, the mother organisation to which the writer belongs, the political standing of the writer and his or her personal values. Similarly the researcher interprets a document with regards to his or her own background. The researcher also needs to understand the wider context of the documents, the time period when they were written, their purpose and how they were prepared, as this might have a bearing on the content.

Concluding remarks

In this chapter the epistemological standing of the author was presented as positivistic, with a foundation based on the ideals drawn from the Socratic perspectives. Abductive and inductive reasoning have been used in the research as the aim of these methods are to find explanations and to draw conclusions from earlier observations respectively. In the early stages of the research process, diverse literature was studied, then the three studies were conducted and, finally, this dissertation was written. The three studies were all qualitative case studies and used the following methods for data gathering: interviews, document analysis and computer based simulations.

3.Literature review

The goal of a literature review is to study, analyse, interpret and present literature regarding a specific field or fields. Reviewing literature is key for any researcher, as it provides insight to what other researchers in the same field are studying and have been studying. A literature review can identify both what are relevant and interesting subjects for the international research community, as well as subjects that are emerging or new. Finally, a literature review links the individual researcher to the wider community by studying the work of others and taking account of their work.

Many fields are linked to the vertical extension of buildings in one way or another; however, only those presented in Figure 3.1 will be reviewed in this chapter. Any development project should aim for sustainable implementation and operation; therefore, each project has to take into account the three aspects of sustainability: economic, environmental and social. Densification and energy-efficient renovation have both been regarded by policy makers as measures for reaching sustainable urban development, as shown in chapter 1. Vertical extension of buildings is a subgroup of both densification and energy-efficient renovation and is, therefore, considered to be a sub-measure. Figure 3.1 presents a hierarchy of research fields linked to the vertical densification of buildings.

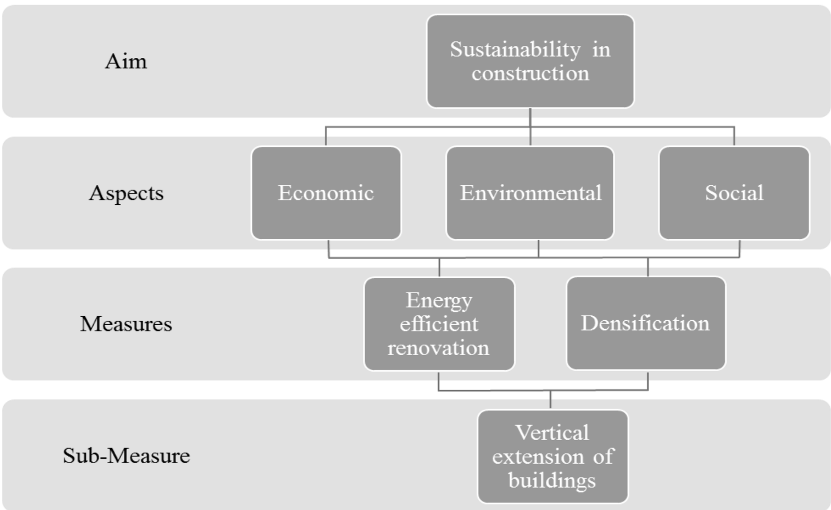


Figure 3.1 A hierarchical breakdown structure of the research fields between sustainability and the vertical extension of buildings.

3.1 Sustainable construction

3.1.1 Sustainability

The concept of sustainable development was first described in *Our Common Future* (WCED, 1987) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The report highlighted social, political and environmental challenges which humanity is faced with, for example, poverty, increasing energy use, high extinction rates and growing population. Somehow, these challenges have to be addressed and, in the report, there are suggestions for strategic goals; unfortunately, the concept of sustainability was at too formative a stage for actual targets and implementations to be suggested. Sustainable development can be divided into three components: economic development, social development and environmental protection (United Nations, 2005). These components are not interdependent and only solutions that meet all of these components can be called sustainable. Even though 30 years have passed since the publication of *Our common future* (WCED, 1987), the threats of human expansion and global warming continue to be two of the most important challenges of our time.

Elkington (1997) explains that, for a company to survive long term it needs to take into account those aspects of sustainability which he described as the triple bottom line. This consists of three aspects: people, planet and profit. The aspect of people refers to the practice of fair treatment of the labour force and the communities in which a company is active. Planet relates to how a company impacts the environment and how the impact can be reduced. A company should evaluate both its production process and its products or services. Profit refers to the financial value that a company has to create in order to develop and grow.

In recent years, more and more wildlife has become endangered and threatened. According to Barnosky et al. (2011), current extinction rates are higher than expected; however, Barnosky et al. (2011) points out that the recent loss of species does not qualify as a mass extinction event and that there is much of the world’s bio diversity left to save. As described in *Living Planet Report 2014* (McLellan et al., 2014), the leading threats to species are exploitation, habitat degradation and habitat loss. Climate change and pollution account for smaller, yet significant, threats.

Almost 30 years have passed since the publication of *Our Common Future* and 20 years since *Cannibals with forks*. During this time, sustainability has moved from a holistic concept to one that is contextualised. In the construction sector, certifications such as BREAM and LEED are used more frequently as the interest in sustainability continues to rise. In Germany, a guideline for sustainable building has been developed (BMVBW, 2001). Aspects of sustainability have also been woven into national standards, for example the standards for design and construction promoted by the UK government (BSI, 2015; 2016).

3.1.2 Economic sustainability

How economic sustainability is measured varies among practitioners, although is typically based on the financial indicators they see fit. Some practitioners prefer payback time, others prefer cash-flow analysis or lifecycle analysis. In this research, lifecycle analysis of financial aspects has been the focus of attention. A lifecycle analysis takes into account all of the financial aspects that a product is subjected to during its life, from cradle to grave (Woodward, 1997). The goal of a lifecycle analysis, as a decision making tool, is to focus on the long-term aspects of a product and not on short-term profitability or low initial costs. Lifecycle analysis has become popular in the construction industry because buildings are expensive capital assets, they have a long lifespan and offer low rates of return compared to other types of investments. The guideline for sustainable building developed by BMVBW (2001) suggest a calculated lifespan between 50 and 100 years. Focusing on the operability of a building or facility from the initiation of its planning phase might yield long-term benefits, such as simpler operation and maintenance measures, which results in lower operation and maintenance costs and a better working environment (Atkin and Brooks, 2015). The benefits of operability planning can be hard to judge early in a project and, therefore, its implementation requires both knowledge and experience. Bogenstätter (2000) has identified four strategies for realising sustainable decision making in regard to the construction of a building.

1. Intelligent design, less resources, less cost.
2. Low tech, low-energy consumption, low maintenance costs.
3. Planning for tomorrow, less cost in the future.
4. More quality for the same money, same quality for less money.

Two popular methods of analysing the financial impacts of an investment are lifecycle costs (LCC) and lifecycle profit (LCP). As the names suggests, LCC is a method that is used to calculate costs and LCP is a method that is used to calculate profit. In both, the discounted net present value method is used to assess the rate of return on invested capital. LCC is a collective assessment of costs regarding investment, operation and maintenance for an object during its economic lifespan (DLMC, 2007). The difference between LCP and LCC is that LCP also takes into account the benefits or the revenues that the object being studied creates. As with any other simulation, the quality of the input will directly affect the output, therefore in order to decrease uncertainty accurate data and knowledge are required. On the next page, the equations for calculating both LCC and LCP are presented.

$$LCC = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} + I - \frac{RV_n}{(1+r)^n} \qquad (1)$$

I	= Initial investment cost
C_t	= Costs year t
RV_n	= Residual value after n years
r	= Calculated rate of return
n	= Economic lifespan

$$LCP = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+r)^t} - I + \frac{RV_n}{(1+r)^n} \qquad (2)$$

I	= Initial investment cost
R_t	= Revenues year t
C_t	= Costs year t
RV_n	= Residual value after n years
r	= Calculated rate of return
n	= Economic lifespan

3.1.3 Environmental sustainability

Environmental sustainability concerns the human impact on the environment both locally and globally. One aspect of environmental sustainability is biological diversity, which in turn concerns wildlife and the ecosystems in which it lives. As noted in chapter 1, the leading threats to species today are exploitation, habitat degradation and habitat loss (McLellan et al., 2014), which all are linked to the human footprint. The human footprint concerns any kind of human development, including cities, towns, agriculture and infrastructure. In order to stop the human footprint from growing any further, there seem to be two options: densification and increased efficiency or putting a stop to population growth. According to the United Nations (2015b), the world population in 2015 was 7.3 billion people and is projected to be 11.2 billion in 2100. In recent years, fertility has dropped; however, the global population is still growing and will continue to grow for a long time. With this in mind, densification and increased efficiency seem to be valid avenues to explore.

According to Crawford (2011), lifecycle assessment (LCA) is a tool which can be used to analyse environmental loads and the impact of a product or process. A LCA takes into consideration all of the emissions, energy and water use, wastes and other releases which can be linked to a product or process. LCA is a cradle-to-grave approach, meaning that every load or impact that occurs during the lifespan of a product or a process is taken into consideration, i.e. extracting raw materials, manufacturing, transport, maintenance and recycling. However, the economic or social aspects are not evaluated in LCA; there are other methods for evaluating them, for example, lifecycle cost evaluates the economic aspects of a product or process. LCA can be used as a tool for decision makers who are interested in the environmental impact of their decisions. Crawford (2011) highlights two objectives that LCA can fulfil: compare the environmental performance of products and processes in order to find the most environmental-friendly option or identifying areas of improvement considering the environmental performance of a product or a process. Even so, the results of a LCA are only indicative as there are no generally accepted methods for translating one environmental impact factor to another – that decision lies with the decision maker(s). Moreover, the results of a LCA can never be better than what the inputs permit, so finding accurate inputs is key.

According to Ayres (1995), LCA might have no, or even negative, influence on the decision-making process if the underlying data are flawed. Available data might be derived from simulations or testing facilities and might not translate into practice. Ott et al. (2014) considers that lifecycle impact assessments are not easily applied in practice, as there is usually a lack of information, time and resources which undermines the impact assessment. In the methodology of IEA EBC Annex 56 (Ott et al., 2014), four stages are taken into consideration: materials production, construction, operation and end of life. During the renovation of a building the following sources should be included: embodied energy use for all renovation measures; on-site energy generation and repairs; operational energy use; and, energy use for home appliances, if possible.

3.1.4 Social sustainability

Curwell et al. (1998) argues that there is a lack of consensus among a wide range of disciplines about what sustainability should involve and this lack of consensus is a hindrance to sustainable development. It will take a collaborative effort, among the stakeholders involved in a project, to identify the goals that the project has to fulfil in order for it to be sustainable. As McCormick et al. (2013), have pointed out, many articles identify collaboration and learning as the foundation for sustainable urban transformation. Moreover, it takes collaborative action, which integrates different knowledge and viewpoints, to be effective in urban sustainability projects.

The definition of stakeholder

According to Freeman (2010), a stakeholder is “any group or individual who can affect or is affected by the achievement of the organisation’s objectives”. This means that an organisation, in order to be effective and responsible, must not only deal with stakeholders that can affect them, but also those that are affected by the organisation’s actions. According to Mitchell et al. (1997) there are three stakeholder attributes (i.e. power, legitimacy and urgency) which need to be taken into consideration. Power is the ability of a stakeholder to bring about the outcome its desires. Legitimate are those stakeholders who act in a desirable or proper manner according to the rules of a certain social system. A stakeholder who urgently needs attention has a time-dependant critical stake in a project; how urgently the stakeholder needs attention depends on how time sensitive and critical the project is.

Stakeholder participation

Fiorno (1990) has identified three arguments for the use of stakeholder participation: substantive, normative and instrumental. The substantive argument is that the judgement of normal citizens is as sound as the judgement of experts; moreover, normal citizens can often contribute much-needed criticism. The normative argument is that citizens ought to be able to participate in decisions that affect them and their community; that it is part of the democratic ideal. The instrumental argument is that effective participation can lead to better decisions, since wider participation takes into account a broader range of values and therefore reduces risks. Nonetheless, Brody (2003) suggests that having all stakeholders present during decision-making processes does not guarantee that better plans will emerge. Instead, Brody (2003) argues that the involvement of specific stakeholders does increase the quality of the plans. As Martínez Àvila (2017) found, early stakeholder participation can prevent conflicts and resistance to change; moreover, participation can create trust and sustainable solutions which better meet the needs of stakeholders.

3.2 Densification

3.2.1 History

In what is modern day Turkey there was an ancient city called Çatal Höyük from around 7400 to 5600 BC. (Hodder, 2006, Mellaart, 1967). It is believed that the city had up to 8 000 inhabitants and 2 000 homes. All the buildings where made out of sun-dried mud-bricks, reeds and render making them strong enough to be a few stories high. During the centuries that Çatal Höyük was inhabited, the city constantly reshaped in a cycle of demolition and rebuilding where the new houses were built on top of the rubble of the older ones. This cycle formed levels where every lower level is older than the level above, with as many as 18 levels having been found in some places. It is here in these cycles of demolition, renovation and new housing that densification has its origin. Thus, the skills and knowledge of how to build denser and higher is as ancient as cities themselves.

Since the Neolithic era, cities have been centres of trade and government; yet, it was not until the industrial revolution that massive migrations from the countryside to the cities took place (Beaudoin, 2003). Better fertiliser, tools and machines made farming easier and produced better yields. This change led to a decrease in demand for labour in rural areas. At the same time, new industries in the cities were generating great demand for labour. This revolution led to a densification and expansion of the cities, which is still ongoing in many parts of the world.

Shortly after the start of the industrial revolution, slums began to take shape in the industrial cities. Hard work, diseases and poverty were what the revolution brought to many citizens (Beaudoin, 2003). In these slums, the death-rates for workers were higher than in the countryside and working conditions were terrible. This led to the development of the first trade unions, equal rights movements and the desire for a better life (Smelser, 1959). During the beginning of the 1900s, an urban planning method was developed. It was a method centred on the creation of garden cities like satellites around a bigger central city (Howard, 2001). The goal of the garden city was to improve the living quality of the working class by providing a healthier environment to live in, compared to the environment within the cities at that time. Howard was inspired by utopianism and imagined a self-sustaining garden city where people would get a chance to live in a smaller, healthier and calmer city than the large, unhealthy cities of his time.

In the 1930s, a new ideal took shape, the American Dream, defined by James Truslow Adams (2012) as “life should be better and richer and fuller for everyone, with opportunity for each according to ability or achievement”. It was an ideal that supported the notion that with hard work there would be great benefits for the individual preforming the work. Over the decades that he followed, this new ideal became the mind-set for western culture and, with it, city planning changed. A house and a car with easy access to everything was the main interest when developing new cities. This had a major impact on existing cities, which together with the garden city movement was the start of what would be the vast urban sprawl that continues to the present (Frumkin et al., 2004). Over the last 50 years, suburban development has been increasing in Europe and there is no indication that it is slowing (EEA, 2006).

3.2.2 Urban sprawl

According to the European Environment Agency (EEA, 2006), urban sprawl not only has a negative impact on energy, land and soil consumption, but it also threatens the very culture of Europe. Frumkin (2002) talks about the many health problems that urban sprawl has created. Most of the problems are linked to car use. Zoning and low density cities more or less force people to depend totally on cars as the only valid transport system. In turn, this leads to air pollution, urban heating, reduced physical activity and automobile-related morbidity and mortality (Frumkin, et al. 2004). Ewing et al. (2014) show the potential effects that urban sprawl have on the human body; they found that obesity and chronic diseases are less common among countries with higher density cities. These problems are also linked to the low density neighbourhoods, were transportation by physical means are not feasible. According to Senbel and Church (2011), suburban development produces higher carbon emissions than compact and mixed-use development with access to public transport. Together these studies show that extensive urban sprawl is actually causing harm to both the population in these neighbourhoods and the global environment. Avoiding suburban development would therefore be beneficial.

3.2.3 Urban densification

Urban densification is the counter reaction to the urban sprawl and is a new trend that focuses more on using the space within city boarders. Urban densification offers a more sustainable city when it comes to public transport, human activity and commerce. For example, by reducing parking space and limiting car use more housing and services can be built. Furthermore, carbon emissions can be reduced, but this requires a properly-functioning public transport system. Additionally, Dogman (2009) argues that a well-planned and effectively-managed dense city will help to limit greenhouse gas emissions. Nabielek (2011) studied the urban densification in the Netherlands and concluded that urban densification will continue to be a necessary tool to sustain and develop urban areas. Cities are dynamic and therefore they should change in order to match the preferences of future inhabitants. According to Nabielek (2011), research by the Netherlands Environmental Assessment Agency has shown that increases in urban density also increase economic productivity and the emergence of new jobs, as well as reducing ethnic and socio-economic segregation. Mumbai, India, suffers from high housing costs due to high demand and restrictions on the growth of the city borders, which in turn have led to large and dense slum areas (Gill and Bhide, 2012). The solution is a vertical densification model which replaces the slums with high-rise buildings. The goal of the model is to provide a win-win-win situation for those involved: the poor get improved housing, for free; the private sector gets to develop valuable land; and, the government gets to improve the quality of living for some of its citizens, as well as creating a city with more recreational space and better infrastructure.

Quastel et al. (2012) highlight some often-overlooked problems linked to densification. In their case study, they showed that densification might also lead to gentrification and claim that “densification clearly has a class-based dimension”. According to Turok (2011), densification projects lead to far-reaching socio-economic changes which might not always be considered. On a similar note, Dogman (2009) highlights that simply assuming that increased density will lead to better development is to be misinformed and will likely not provide any sustainable benefits. However, gentrification can in certain cases be used as a tool for city planners who want to change a neighbourhood or area. Even though a shift in the characteristics of the local population is wanted, Kupke et al. (2012) showed in their study that densification might not lead to a change in the socio-economic status, ethnicity, family makeup or mobility of a neighbourhood.

Using a map-based internet questionnaire survey, Schmidt-Thomé et al. (2013) showed that people generally prefer densification levels similar to those they currently inhabit. In a similar study, Kyttä et al. (2013) showed that in denser urban areas people are generally more open to densification compared to people in less dense areas, such as suburban development, who in turn are generally less open to densification. Rosol (2013) argues that the EcoDensity initiative in Vancouver, Canada, was an attempt to push densification, even though densification had a bad reputation among citizens. By linking EcoDensity to sustainability, affordability and liveability, policy makers hoped that it would appeal to the public. However, the opposition questioned the link between densification and sustainability, which instead led to a lack of consensus among the public. These three studies highlight a problem with densification. It is likely that some aspects of an area will have to change or be removed during a densification process even though these aspects led the local residents to move there in the first place.

3.2.4 Densification and policy making

An interesting citation from a municipal report on densification (Malmö stad, 2010) highlights two of the challenges regarding densification, social acceptance and political hegemony. “In order to succeed with densification as a growth strategy will require more focus to be put on opportunities rather than on problems and restrictions” (freely translated by the author). This citation shows that densification projects in Malmö have faced criticism and are being challenged by it. This also shows that policy makers want to densify the city and are using their power, by the use of documents like this, to realise more densification projects. Just as in Vancouver (Rosol, 2013) densification is being pushed by policy makers. By associating densification with sustainability and focusing more on the benefits than on the consequences, policy makers can promote densification even though densification has negative aspects that ought to be highlighted as well.

3.3 Energy-efficient renovation

In chapter 1, a few policy targets related to energy use were presented, the goals of which were to reduce the energy use of the building stock as a whole. These targets can be met by either building new, low-energy buildings or reducing the energy use of the existing building stock; the latter can be achieved through energy-efficient renovation. In this research, energy-efficient renovation is defined as a package of measures, a renovation concept, which focuses on reducing the energy use of a building.

Studies have shown that energy-efficient renovations are possible for a majority of the existing building stock and that there are a wide range of renovation measures that can be applied; however, not all of them are financially viable. Keoleian et al. (2000) studied lifecycle energy and costs for single-family houses in USA and concluded that 60% energy reductions are possible; however, such a renovation resulted in pay-back period of about 50 years, or longer, if energy prices stay stable or fall. Amstalden et al. (2007) analysed energy-efficient renovations in Switzerland in order to find financially-viable solutions; they showed that many energy-efficient renovations were almost, but not really, financially viable. Verbeeck and Hens (2007) developed a global methodology to optimise low-energy buildings, but none of the concepts studied appeared to be financially viable with current energy prices. More recently, Boverket (2013) showed that energy-efficient renovation projects which exceeded the building code requirements struggled to reach financial viability. As part of the IEA Annex 56 project, Mørck et al. (2014) produced a brochure of shining examples regarding energy-efficient renovation projects. Here, most of the projects have a long payback time.

There is opportunity for energy-efficient renovation, as noted earlier. Keoleian et al. (2000) showed that reducing energy use by 60% is possible. Moreover; renovating buildings instead of demolishing and rebuilding is supported by Itard and Klunder (2007), who showed that transforming a building is much more environmentally efficient and uses about 40-60% less embodied materials depending on the building and its lifespan. The studies cited above have shown that many energy-efficient renovations are close to being financially viable; however, in order to realise a renovation concept, it must reach the required rate of return and be economically sustainable. Perhaps solutions, measures and more efficient production methods could be found which would enable more energy-efficient renovation.

3.4 Vertical extension of buildings

In this research three methods of extending a building vertically have been identified: total demolition plus new construction; demolition of roof plus extension with new roof; and roof raising. Total demolition plus new construction is commonly used when the existing building has reached the end of its life and is no longer suitable for operation or if the demand for housing can motivate the demolition of the existing building and the construction of a new, larger building. Although total demolition plus new construction would result in a larger and higher building, it cannot be considered a vertical extension since the existing building is demolished. Demolition of roof plus extension new roof and roof raising, on the other hand, can both be considered methods for vertical extension. Demolition of roof plus extension and new roof have been studied in study 1 and 3; however, roof raising has not been studied, since no data have been found. Whilst examples of roof raising on industrial buildings have been found, hydraulic lifters are used to raise the roofs in the examples. As an alternative to hydraulic lifters, a crane can also be used to lift the roof of a building; however, cranes might not be applicable on larger buildings since there are limitations in the weight a crane can lift.

Combining vertical extension of buildings with energy-efficient renovation could provide financial benefits and, in some cases, enable energy-efficient renovation of those buildings. Cukovic-Ignjatovic and Ignjatovic (2006) studied links between renovation and building extension, with the study suggesting that only an energy-efficient renovation would not be financially viable; however, a lateral plus vertical extension would provide the best economic outcome. Jovanović-Popović et al. (2006) claim that, in their case study, a preliminary cost analysis showed that it was possible to finance all refurbishment measures by performing a vertical extension of the building and then sell the added apartments. However, no analysis or data were presented in these two papers to support the claims.

Bergenudd (1981) developed a checklist in his doctoral thesis which could provide the basis for implementating the vertical extension of a building. In this checklist, seven topics were identified: urban planning and regulations, supplementary functions, structural framework, utilities, economy, construction management and design. Even though this thesis was written 35 years ago, the checklist is still relevant in many respects. For example, Bergenudd (1981) argues that a vertical extension increases the efficiency of existing infrastructure, which is still one of the arguments for densification. Moreover, Bergenudd discusses possible energy use reductions using vertical extension, and even though we now have better tools for calculating and simulating energy use, the topic is just as relevant today.

Due to high demand for housing in the larger cities of Sweden, vertical extensions have recently become more popular. In their interview-based report, Lidgren and Widerberg (2010) identify six success factors for the vertical extension of buildings:

1. demand for housing;
2. alternative forms of investment;
3. architect involvement in the early stages;
4. make inventory of the existing building;
5. prefabricated elements; and
6. resident involvement.

In order to motivate a change in a city's detailed plan there needs to be a high demand for housing. Since many housing companies have high required rates of return, alternative ways to finance the extension might be needed; increasing rent is not always sufficient, instead selling some apartments as conduminiums could help finance the project. Involving an architect in the early stages of a vertical extension project can allow for not only efficient use of the extension but also improvement of the existing building. The structural framework of the existing building, construction site management and transportation have to be tested; in addition, the cultural and historical value of the building have to be taken into consideration. If there is a common denominator in the design of the existing building, the use of prefabricated elements might be viable and yield lower production time. Lidgren and Widerberg (2010) finish their conclusions by highlighting that the involvement of residents might lead to more holistic thinking and a better result. Regarding the structural framework in the vertical extension, Bergsten (2005) suggests the use of light-gauge steel systems. The low weight of light-gauge steel systems makes them practical for vertical extensions since less resources have to be spent strengthening the existing building. Light-gauge steel systems also offer opportunity for prefabrication; however, prefabrication focused on vertically extending buildings might not be practical, due to multiple limiting factors.

Concluding remarks

This chapter has provided the theoretical framework for this research and it highlights the links between sustainability and vertical extension of buildings. First, the three aspects of sustainability are described, how they relate the construction industry and how they can be measured and managed. In order to get a better understanding of densification, the main historical events have been presented; additionally, the negative effects of urban sprawl and opportunities and challenges of urban densification have been discussed. From the literature studied it can be concluded that energy-efficient renovation of the existing building stock is necessary in order to reach the policy targets regarding energy; however, energy-efficient renovations are typically expensive and have long payback times. Finally, literature regarding the vertical extension of buildings was presented, prefabrication and financing the extension by selling the added apartments are highlighted as success factors.

4.Empirical studies

The purpose of empirical studies is to provide evidence in order to support an argument. Empirical evidence is observations and experiences gathered by the researcher during an encounter with a specific phenomenon and can typically be separated into two categories: quantitative and qualitative. Empirical studies are traditionally supported by researchers who prefer to rely on observations and experiences, instead of theoretical argumentation.

The three studies, which were conducted as part of the research, are presented. The studies consist of three case studies; thus, only qualitative empirical studies have been conducted. A summary of each study can be found in table 4.1.

4.1 Study 1

This study was part of the Swedish contribution to the International Energy Agency (IEA) *Energy in Buildings and Communities Programme* (EBC) Annex 56 (Cost effective energy and carbon emissions optimisation in building renovation). IEA EBC Annex 56 consisted of several studies, one of which was a multiple case study of best practice examples of energy-efficient renovation. The Swedish contribution to this study, presented as Study 1 in this research, was a case of a typical Swedish multi-family building from 1971, which needed renovation (see figure 4.1). The aim of this study was to examine the effects of energy-efficient renovation in a realised project. The researchers' goal during the study was to learn about energy-efficient renovation and economic and environmental sustainability. The following factors were studied: construction costs, lifecycle costs, energy use, CO_2 emissions, primary energy use, non-renewable primary energy use and co-benefits; in addition, the renovation measures were explained. This study can be linked to research questions 1 and 2 as economic and environmental aspects were studied and, as seen in paper 2, the housing company later chose to extend similar buildings vertically during renovation. The study can be considered abductive as the focus was to examine one building in detail.

Table 4.1 Summary of the three studies.

	Study 1	**Study 2**	**Study 3**
Aim	Study the effects of energy-efficient renovation in a realised project	Study the current practice of stakeholder participation in densification projects amongst real practitioners	Study the development process regarding the implementation of vertical extension of buildings
Research questions	1	1	2
Research strategy	Abductive	Inductive	Abductive
Data gathering method	Case study	Case study	Multiple case study
Related research fields	Economic and environmental sustainability and lifecycle analysis	Stakeholder participation, social sustainability and densification	Development processes, vertical extension of buildings and diffusion of innovation
Study conducted by	Åke Blomsterberg and Rikard Nilsson	Carlos Martinez-Avila and Rikard Nilsson	Rikard Nilsson
Papers	Paper I and Paper II	Paper III	Paper IV

The goal of the study was to obtain a deeper understanding of the renovation process and the effects of the said renovation; therefore, a case study was chosen. The majority of countries participating in IEA EBC Annex 56 performed a similar study and so the cases could be compared to one another. In order to learn more from the case study, four renovation concepts were developed and studied, where one of them represented the realised renovation. The methods chosen for analysing the renovation were: energy use simulation, lifecycle cost analysis, lifecycle impact analysis and co-benefits analysis. The inputs were gathered from interviews, site visits and document analysis facilitated by the housing company and the contractor. The study was conducted by Åke Blomsterberg and Rikard Nilsson. The former had a leading role in the Annex 56 project and therefore had a leading role in this study; he also contributed with other studies for IEA EBC Annex 56. The latter's main contributions were data gathering and lifecycle cost analysis for the Swedish case study, as well as reviewing parts of the IEA EBC Annex 56 deliverables. The results from this study are presented in papers I and II.

Figure 4.1 Photograph taken before (left) and after (right) the renovation. Photographs taken by Åke Blomsterberg.

4.2 Study 2

The aim of this study was to explore the current practice of stakeholder participation in densification projects with practitioners. The goal of this study was for the researchers to learn from each other's work, as well as identify possible future collaboration. This study can be linked to research question 3, since social aspects and densification were studied. The researchers agreed on an inductive approach, as little was known about the current practice of stakeholder participation. An exploratory study was considered appropriate. Semi-structured interviews were designed since they allow for a more flexible and interactive approach, compared to other inductive methods such as surveys. The interviews allowed the researchers to ask the questions to which they were seeking answers, as well as allowing the interviewees to share experiences and give feedback during the interview. Another benefit of semi-structured interviews is that the interviewer can add and remove questions as they see fit, based on the feedback after each interview, in order to improve the interview guide and the quality of the coming interviews.

The interviewees were asked questions regarding stakeholder participation, sustainability and densification. A total of ten interviews were conducted with practitioners all of who had worked with stakeholder participation in densification projects. The interviewees represented: city planners, civil servants, municipal developers, facility managers, private developers and housing cooperative members. Carlos Martinez-Avila initiated the study by proposing the subject. Carlos Martinez-Avila and Rikard Nilsson both participated in the search for suitable interviewees, the interviews, the transcription of the interviews and the early stages of the analysis; however, the former conducted the majority of the analysis and the last steps of the study. Anne Landin and Stefan Olander both contributed to the paper, but had a low profile during the actual study. The results from this study are presented in paper III.

4.3 Study 3

The aim of this study was to examine the decision process concerning the implementation of vertical extension projects. The researcher's goal was to learn which factors or aspects in the development process led to successful implementation of vertical extensions and to gain an introduction to the diffusion of innovation. This study can be linked to research question 4, since success factors to the implementation of vertical extensions was studied. The study can be considered abductive as little was known about the development process regarding implementation of vertical extensions. In addition, the researcher tried to find explanations of how the development process affects vertical extension projects.

A multiple case study was chosen as the alternative, as a single case study was considered insufficient and a survey was considered non-specific as well as providing insufficient detail for explanation. A total of four cases were studied, two which had already been vertically extended (see figure 4.2), one which is planned to be extended within a few years and one which was stopped soon after the procurement process started. The focus for the case studies were the development process, the decisions which which the housing companies faced and significant enablers and barriers to the implementation of the projects. The multiple case study involved interviews, site visits and document analysis. Rikard Nilsson alone conducted this study. The results from this study are presented in paper IV.


Figure 4.2 The two realised vertical extension projects. Photograph taken by Rikard Nilsson and Åke Blomsterberg.

Concluding remarks

In this chapter the three studies which this research comprises were described. The first study was a case study of a multifamily building, where energy use and renovation measures were studied. The second study was a case study of the current practice of stakeholder participation in densification projects; in this study, ten interviews were undertaken with industry actors. The third study was a multiple case study of four multifamily buildings which had been or were planned to be extended vertically. This study focused on success factors and the implementation process.

5.Findings and analyses

In this chapter, the findings from the three studies are presented after which an overall analysis is presented. The purpose of the analysis is to reflect on how the findings can be used to answer the research questions. The full-length papers can be found in the appendix.

5.1 Study 1

This study was part of the IEA EBC Annex 56, where case studies would provide examples of realised energy-efficient renovation projects. The case from study 1 was the renovation of a multifamily building from 1971, which can be described as a typical building from the so called *million homes programme*. The factors analysed in this study were: energy savings, lifecycle cost analysis, lifecycle assessment and co-benefits. Input was gathered from interviews and document analysis provided by the housing company and the contractor.

Four renovation concepts were studied: reference case, v1-DH, v2-DH and v3-DH (DH stands for district hot water). In the reference case, a small number of improvements were made, none of which affected the energy use. Case v1-DH was supposed to embody the building code and therefore had improvements in both the building envelope and its technical systems. In v2-DH only the building envelope was improved. Finally, in v3-DH, significant improvements were made to both the building envelope and the technical systems; v3-DH, is a simulation of the realised renovation. This latter renovation resulted in an energy reduction of 65% and a significant improvement in living standards. The monitored energy savings were 117 kWh/(m^2·year), from 174 to 57 kWh/(m^2·year). Facility electricity did not increase in spite of the installation of more technical equipment, since energy-efficient fans, lighting and other appliances were installed. The energy saving measures included added thermal insulation to the entire building envelope, low-energy windows, installation of ventilation with heat recovery and individual metering of domestic hot water.

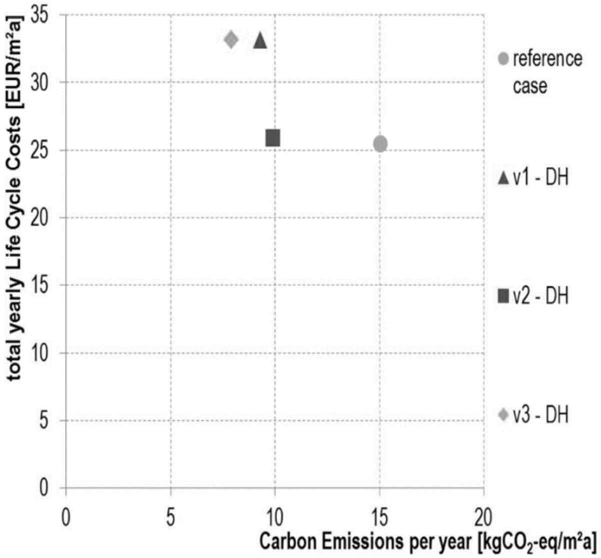


Figure 5.1 A graph of carbon emissions per year as a function of total yearly lifecycle costs.

Figures 5.1 and 5.2 show that the reference case is the renovation concept with the lowest total yearly lifecycle costs and v3-DH, the concept which was realised, has the highest. It should, however, be noted that there are other factors, such as new plumbing and rent changes, which have not been taken into account here (for more information see paper II). Using the guidelines of IEA Annex 56, none of the renovation concepts were financially viable, even over a 60-year calculated lifespan.

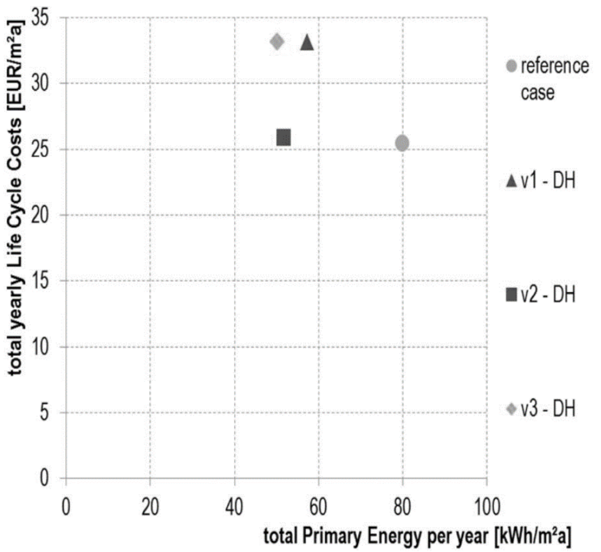


Figure 5.2 A graph of total primary energy per year as a function of total yearly lifecycle costs.

A lifecycle assessment showed a reduction in carbon emissions for all of the renovation concepts, as seen in figure 5.1. Case v3-DH had the lowest carbon emissions – just 8kgCO_2-eq/m^{2}a – which is almost half of the emissions in the reference case.

Similar patterns were found when primary energy was assessed, as shown in figure 5.2. These are, however, relatively small improvements, since the district heating is mostly produced from renewable resources. If other renovation materials with lower environmental impact had been used then the carbon emissions and the primary energy could have been further reduced.

The co-benefits of the realised renovation include reduced draught, reduced exposure to temperature fluctuations and improved appearance. According to a survey undertaken by the housing company, the tenants have appreciated the improvements provided by the realised renovation, which resulted in better thermal comfort, indoor air quality and noise control. It should be noted that only the tenants from four of the sixteen apartments moved back after the renovation. The two main reasons for this were a rent increase and problems related to movement.

Study 1 extension

Study 1 was extended in order to study the renovation plus vertical extension that the housing company decided to realise in the remaining five buildings. The main reason for the extension was to improve profitability from the first renovation. The method chosen for examining the renovation concept was a lifecycle analysis. The inputs for the analysis were gathered from interviews, with supporting documentation provided by the housing company and the contractor.

In this extended study, four concepts were developed which were analysed in order to find the most appropriate renovation concept. The first concept, minimalist renovation (Min.), focused on the living standards of the residents and ignored any of the energy improvements. The second concept, code-compliant renovation (CC), simulated a renovation complying with the building code. The third concept, low-energy renovation (L-E), simulated the first realised renovation, which is the same as renovation concept v3-DH from earlier: this concept has a much higher focus on energy improvements. The final concept, low-energy plus vertical extension (L-E VE), is similar to the low-energy concept except for the two added floors. The lifecycle analysis consisted of six steps: lifespan, investment, rent changes, operation savings, current net operating income, net present value and profit. The inputs of the four concepts and the outputs of the analysis are presented in table 5.1.

Table 5.1 The result of the lifecycle analysis.

	Min.	**CC**	**L-E**	**L-E VE**
Lifespan	33y	33y	33y	33y
Total investment	608.2	800.8	858.3	734.5
Rent increase	8.6	13.9	17.1	30.5
Operation savings	1.7	9.0	11.7	8.0
Current net operating income	13.5	13.5	13.5	9.2
Net present value	442.5	678.7	789.7	888.1
Result	-165.7	-122.1	-68.6	153.6
Return on capital	2.76%	3.22%	3.50%	4.59%

Units: lifespan in years, return on capital in percent and the remaining in € per m^2 of floor area.

As seen in table 5.1, the results from the analysis show that only the fourth concept, low-energy plus vertical extension, meets the required return on capital of 3.8%. Since these buildings are typical of *the million homes programme*, perhaps similar renovations can be realised elsewhere.

5.2 Study 2

The study was undertaken in order to find the links between densification projects and stakeholder participation. The study's exploratory nature and focus required a qualitative method; therefore, an interview-based study was the chosen. The findings and analyses of study 2 were categorised into seven themes.

Theme 1: Challenges and opportunities for urban densification

One of the challenges highlighted by the interviewees was to identify areas which were suitable for densification, meaning that the area is neither efficiently used nor cherished by the local residents. Identifying these areas is challenging as low density areas typically have a recreational value for the residents.

The majority of the interviewees stated that densification does not automatically lead to a sustainable development. Even so, they all agreed that a denser city with reduced car traffic, mixed housing types and increased efficiency could lead to a more sustainable development. Many interviewees also said, that socioeconomic resident diversity and mixed-use buildings would be beneficial and that densification, if used correctly, could enable such development.

Theme 2: The importance of collaboration among a wide range of stakeholders

Urban densification projects are, in general, complicated since they affect many stakeholders. Typically, local politicians and housing companies are searching for possible areas suitable for densification and residents and organisations in these selected areas are typically negative towards densification. Since the residents and organisations, most likely, have chosen to live and operate in those areas for the qualities that these areas have, any suggested change which might threaten these qualities will be faced with negativity. Stakeholders attempt to influence any suggested development that affects them, so that future development better meets their own needs. The interviewees claimed that involving more stakeholders can help to achieve a development that satisfies more needs.

Theme 3: The Swedish planning and building act and stakeholder participation

The Swedish planning and building act states that when a proposal for a development plan is drafted, the municipality should consult stakeholders who have an essential interest in the development plan. The development plan has to be publically presented at consultation meetings at least twice and the feedback from those should be presented in a consultation report. There are, however, no other requirements for stakeholder involvement, only suggestions; how this is interpreted varies among the municipalities and their officers. In some cases, the municipality's officers have done nothing more than holding the two mandatory consultation meetings required; in other cases, the officers have done significantly more, for example workshops, interviews and transect-walks, i.e. actively seeking participation from stakeholders.

Theme 4: Stakeholders and purposes for stakeholder participation

The developers and housing companies reported that they occasionally do market surveys of residents, customers and businesses in order to identify improvements to their planned development and so increase the value of the development. Many interviewees claimed that the opponents and their concerns ought to be addressed early in the development process, in order to start a discussion and address the concerns appropriately. If concerns are raised in the later stages of the planning process little to nothing can be done to address them. Interviewees stressed that it was challenging to identify and engage stakeholders early in the development process.

Theme 5: Individuals and groups experiences and abilities as driving forces for stakeholder participation

Municipality officers pointed out that individuals and groups, within their respective organisations, could conduct a stakeholder participation process if they wanted and could argue for its benefits. Certain project leaders and project groups in charge of planning processes were identified as strong enablers.

Theme 6: Stakeholder participation practices, contribution, enablers and challenges to the organisation

Many interviewees stated that they were trying to engage in more forms of participation; however, since densification projects are complex, many are uncertain of the value that participation might bring. Additionally, there is a lack of experience and understanding of participation processes among many stakeholders, which makes it challenging for these stakeholders to understand the motives of the process and their contribution.

Theme 7: Institutionalising stakeholder participation

According to the interviewees, the initiative for stakeholder participation typically originates from individuals with interests in the process and not from the higher levels in organisations. Therefore, stakeholder participation competences and skills in the process often remain on an individual level; thus, collecting and systematising this knowledge would have long-term benefits for parent organisations with interests in stakeholder participation.

5.3 Study 3

This study examines the development process for the implementing vertical extension buildings and links it to the diffusion of innovation. Four cases of vertical extension of buildings were studied, two which were realised, one which was cancelled and one was in the planning phase. From study 3, six steps were identified as key for the development process: these can be seen in figure 5.3.

Opportunities for vertical extension

Finding a suitable location and building for vertical extension is key. Features to look for are high market demand for housing, sufficient infrastructure, higher surrounding buildings and significant amounts of living space from vertical extension.

Strategies for implementation

Four strategies were identified as relevant to the implementation of vertical extension projects: evaluating structural framework, utility planning, financial viability and production viability. Only when and if all of these four strategies are established is it recommended to continue with the process.

Detailed planning

Since vertical extension projects involve many stakeholders, a stakeholder participation process could be beneficial as it can be used as a tool in order to gain acceptance from the stakeholders. Legislation requires stakeholder consultation for any development project, see it as an opportunity for feedback instead of a necessary evil.

Concept development

There are three points to keep in mind when developing a concept: input, synergies and comparability. Each concept has unique inputs which can be gathered from earlier studies, experience, experts and contractors. Finding synergies can greatly improve the odds of implementation; synergies might be found when comparing the inputs and the knowledge gained from the earlier steps of the development decision process. Finally, each concept has to be comparable with the others.

Evaluation

Individual property owners have their own basis for measuring success and risks in a project. The aspects sustainability should be considered in the evaluation, in order to achieve a more enduring development.

Procurement

There are several risks that contractors face in a vertical extension project, which they might not face in other construction projects. A small construction site, highly-trafficked infrastructure, working on a high elevation and complaints from local residents. These risks have to be taken into consideration before starting the procurement process.

Lessons learnt from the case studies

From the case studies, several significant success factors for the implementation of vertical extension building projects were identified. Collaboration between the property owner and the municipality can be beneficial as the latter will lead the detailed planning process. Mitigating risks in order to simplify the work for contractors can hopefully increase the quality and quantity of bids. If the concept development and evaluation steps are well structured and documented, the property owner can go back and make changes as new opportunities present themselves. Planning different apartment layouts for the apartments in the extension, then those in the existing building, will attract a wider market for the building. Vertical extension projects are complicated and therefore expensive. For a vertical extension project to be financially viable, both synergies and the amount of living space in the extension have to be maximised.

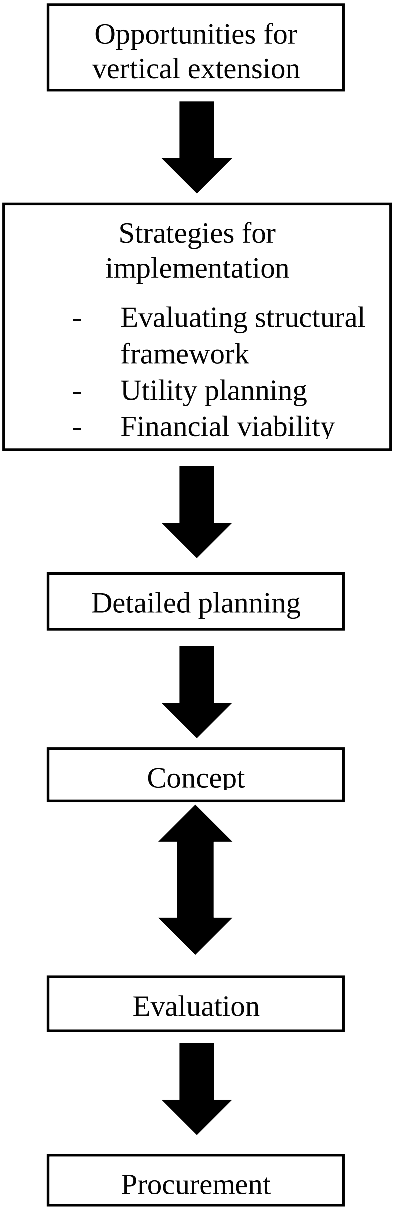


Figure 5.3 The development process.

5.4 Analysis

In this section, analysis of the findings from the studies are presented. The structure of the analysis is based on the research questions since the goal is to break down the findings and connect them to the aim and objectives of the research. The environmental, financial and social implications of extending buildings vertically are analysed separately, followed by the success factors to extending buildings vertically and diffusion of innovation.

5.4.1 The environmental implications of extending buildings vertically

From what has been found, it can be argued that vertical extension of buildings can reduce or stabilise the human impact on the environment. Building higher and extending existing buildings will reduce habitat destruction, since more people can then live within the urban boundary. As outlined in paper I, an energy-efficient renovation can bring very significant reductions to the primary energy use and global warming potential. Finding solutions that enable energy-efficient renovations on a larger scale could, therefore, make significant contributions to the Swedish zero net emissions 2050 target. Vertical extension could, as shown in paper II, be one such solution.

Vertical extension of buildings can also bring benefits to the human living environment. Densification can bring benefits such as less car traffic, reduced obesity, better local services and, in general, a more attractive city (Frumkin, 2002, Boverket, 2014, Nabielek, 2011). Moreover, instead of densifying the urban environment by building on car parks and recreational spaces such as public parks, vertical extensions would preserve these spaces and increase the use of them. There are, however, negative environment effects too, with less sunlight on the streets and neighbouring buildings, increased use of recreational spaces and urban scale problems. Furthermore, some scholars argue that benefits of densification, such as reduced car traffic and health benefits lack support, since a person moving from a rural town to the city centre will be more exposed to pollution (Næss, 2014). However, it seems likely that densification will continue to be used as a tool for managing population increases in cities (Regionplanekontoret, 2009; Göteborgs Stad, 2014; Malmö stad, 2010). A balance must therefore be found – one in which the vertical extension of buildings is a part.

An interesting result, which was not highlighted in paper I or II, was that the heating source made a huge difference to the environmental impact. Figures 5.4 and 5.5 shows this result. From a primary energy perspective any concept, using district heating as its heating source, was significantly better than any concept using fossil fuels, i.e. oil or gas, which in turn was significantly better than any concept using electricity (see figure 5.4). On the other hand, from the perspective of carbon emissions, the concepts using electricity where in the same cluster as those using district heating (see figure 5.5). This result shows that from a primary energy perspective electric heating is ineffective compared to both fossil fuels and district heating and, considering both primary energy and carbon emissions, fossil fuels are also ineffective. In this study, district heating proved to be the most appropriate heating system. Regardless of which renovation measures were considered, the heating source significantly impacted the environmental sustainability; and therefore, proved to be one of the most important aspect to consider during renovation.

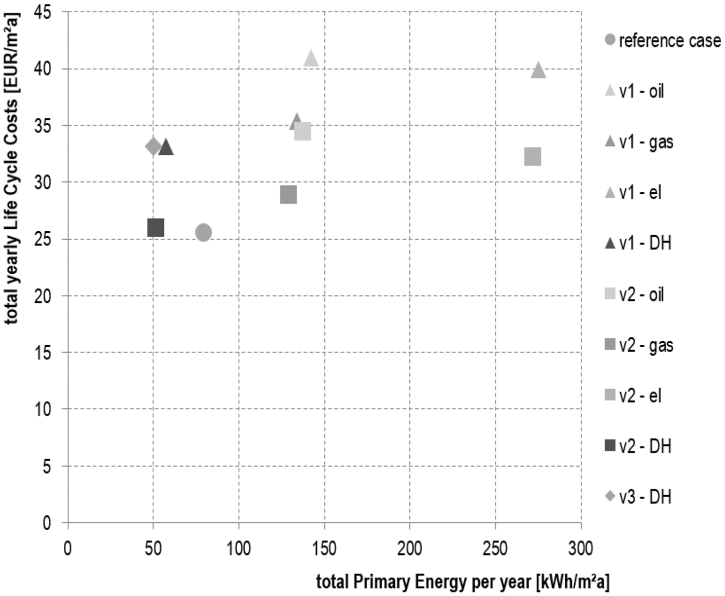


Figure 5.4 A graph of total primary energy per year as a function of total yearly lifecycle costs.

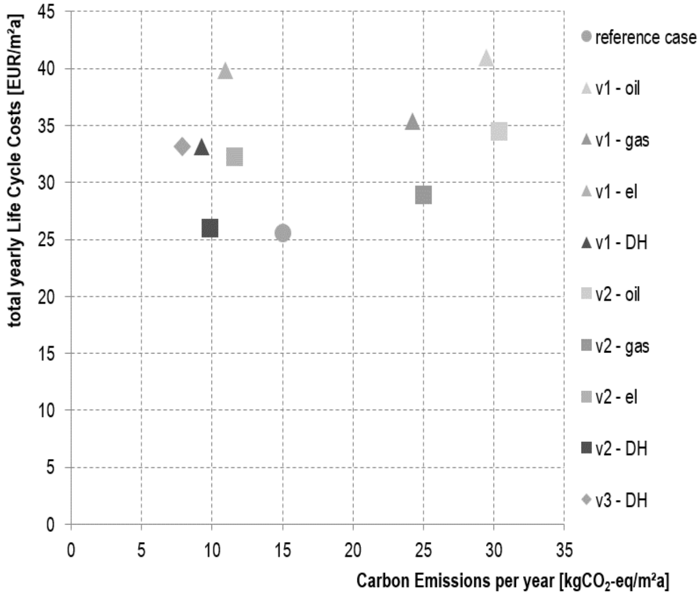


Figure 5.5 A graph of carbon emissions per year as a function of total yearly lifecycle costs.

5.4.2 The financial implications of extending buildings vertically

As shown in papers I and II, finding the appropriate renovation concept can be challenging. Identifying realistic and efficient energy improvements can help in finding a more financially-viable concept; however, in the papers, none of the renovation concepts were found to be viable except for low-energy plus vertical extension. In order to renovate the old building stock, new solutions are need that can help renovation projects achieve financial viability. If no such solutions are found in the coming years then energy-efficient renovations will continue to be rare. It seems probable that vertical extension renovation concepts have the potential to be implemented on a larger scale. Three indicators for this have been found during the research: the building in paper II is typical of the 1970s, three other cases of vertical extension were identified in paper IV and during conversations and interviews with practitioners from industry many claimed that they were planning or already had vertically-extended buildings. A large-scale implementation could make a significant contribution to the 2020 and 2050 energy targets.

Other methods to help reach the 2050 goal could be stricter building code requirements and more generous incentives. Although this research has not studied policy making *per se*, it seems unlikely that changes in the building code, which would force property owners to perform energy-efficient renovation, would be implemented. Such a change would punish many property owners and could spell the demise of many historical buildings. More likely is that policy makers will continue to work with incentives, increasing taxation of fuel and subsidising renewable energy sources such as photovoltaic systems, as these have the benefit of slowly changing the market. Finding solutions that are financially viable today and offering property owners resilience to future changes would most likely be preferred to policy changes.

5.4.3 The social implications of extending buildings vertically

Gentrification is an effect of urban planning and development and should be considered, especially in the case of renovation projects. Raising rents might force some tenants out of their apartments. An example of gentrification can be found in study 1 and paper I, where only four out of sixteen tenants moved back after the renovation. Vertical extensions can be built without affecting the existing building, as shown in case 1 in paper IV; however, it means that opportunity to renovate the existing building is missed.

Another social issue identified is that of densification changes that make existing urban environment more compact. People typically live in an environment where they are comfortable with the level of density (Schmidt-Thomé et al., 2013, Kyttä et al., 2013). Increasing density can therefore cause discomfort among residents and lead to complaints. This argument was supported by an interviewee in study 2, who felt that people living in larger cities were often more open to densification projects than people from smaller cities. Densification projects therefore ought to be implemented slowly over time and in sympathy with the existing urban scale.

Densification projects typically involve many stakeholders and finding tools to support the involvement of these stakeholders can be challenging. According to the interviewees in the study 2, there are a lot of stakeholders who felt excluded from the planning process and many practitioners were not sure which stakeholders to include, except for those regarded as key stakeholders. Not all stakeholders bring equal value to the project. As suggested by interviewees in study 2 and by Brody (2003), identifying, inviting and consulting certain stakeholders who can provide specific knowledge and resources might lead to better results, rather than simply inviting every stakeholder to participate. A stakeholder participation process can be one tool to help include more stakeholders in the planning process, assuming that appropriate stakeholders have been identified, invited and want to participate. As discussed in paper III, most stakeholder participation initiatives are left to individuals with an interest in such a process.

5.4.4 The success factors to extending buildings vertically

As shown in study 1, reaching financial viability in energy-efficient renovations can be challenging. Energy-efficient renovations are considered expensive since finding and allocating large amounts of capital over long periods of time can be difficult, especially if the renovation costs are comparable to those of newly-built housing. Vertical extensions can in certain cases enable energy-efficient renovation, as shown in study 1 and paper II. The main reason why a vertical extension enabled the renovation of the case in study 1 was the synergistic effects that the vertical extension provided. Since the renovation included expensive measures, such as removal and installation of new utilities and reconstructing the roof to allow for the new ventilation system, the added cost for these measures for the apartments in the extension were small in comparison.

As argued earlier, people generally choose to live in an urban environment and accept a certain level of density. Changing the density of this environment might lead to a level of density that they would not have chosen, given this option. A vertical extension does not occupy any recreational space; therefore, an extension might not face the same level of opposition. Even though, an extension will increase the use of that recreational space. Whilst densification projects might face criticism from local residents, a high market demand can be a strong incentive for densification and vertical extension of buildings as seen in paper IV.

In paper IV, several barriers where identified: structural framework, utility planning, financial viability and production viability. In order to cope with these barriers, strategies have to be found during the initiation and the planning phases of a vertical extension building projects. The strength of the existing structural framework has to be evaluated and, if necessary, reinforced in order to support the added floors. The utilities for the added apartments have to be planned; if possible, using existing utilities and a vertical shaft. As argued earlier, finding financially-viable projects is challenging and so an early financial viability test might eliminate certain concepts or perhaps even stop the project, thus avoiding unnecessary costs. Assessing production viability early on will clarify how a construction site can be established and help to mitigate risks associated with construction in an urban context. Moreover, avoiding and mitigating risks, which the contractor would otherwise have to manage before the procurement process, could lead to more and better bids.

5.4.5 Diffusion of innovation

Rogers (1995) defines diffusion of innovation as: “the process by which an innovation is communicated through certain channels over time among the members of a social system”. Innovation often starts off slowly, gaining a few early adopters.

If there is a niche to fill and the innovation proves successful the innovation can reach its “take-off” stage. As of yet, the researcher would argue that the vertical extension of buildings has yet to reach its “take-off” stage, at least as an enabler of energy-efficient renovation. The “take-off” stage is the stage when the innovation has gained popularity and adopters. However, Fichman and Kemerer (1999) claim that there is assimilation gap and that observers who experience positive sales data regarding an innovation should not jump to the conclusion that the innovation is being widely used. They define an assimilation gap as: “*the difference between the pattern of cumulative acquisitions and cumulative deployments of an innovation across a population of potential adopters”*. In paper IV it is suggested that there is a similar gap between the publicity of vertical extension of buildings and the wider implementation of that innovation. Even though the vertical extension of buildings has been implemented in certain cases, there are still many opportunities for further implementation. This research has contributed to the diffusion of vertical extension of buildings as an innovation, since knowledge regarding success factors has been shared and the development process presented in paper IV simplifies decision making.

Concluding remarks

The results from the three studies were presented in this chapter. The first study showed that finding financially viable renovation concepts was challenging, even though significant energy savings can be made; however, by extending a building vertically, a financially-viable concepts was found. The second study showed that many municipal practitioners showed support for a stakeholder participation process; however, such a process was often initiated, implemented and lead by individual proponents. The result of the third study was a proposed development process, which highlights some of the most significant success factors to extending a building vertically.

The analysis highlights the impacts on the aspects of sustainability of extending buildings vertically. An energy-efficient renovation can reduced the energy use by up to 65% is the conditions are right. The heating source is one of the most important aspects to consider if the aim is to reduce environmental impact. Since the buildings studied had structural frameworks of concrete and brick and were built around 1960-70, perhaps similar buildings can be found which are suitable for extension.

6.Discussion

The aim of the discussion is to highlight the strengths and weaknesses of the research and to reflect on how it might have been improved upon. The discussion can therefore be considered an introspection of the research. Reviewing and reflecting upon one's own work is supported in the Socratic perspectives as it will strengthen knowledge stability and recognise fallibility. Researchers should reflect on their research; not only as a means to defend it, but also as a means for self-improvement.

6.1 Research approach

Since densification and energy-efficient renovation are considered to be methods for achieving more sustainable development, it was natural to study the vertical extension of buildings from the perspective of sustainability. Research question 1 reflects this approach; however, the question might be considered too broad, as it tries to link all three aspects of sustainability to the vertical extension of buildings. Alternatively, focusing on one of the aspects instead of all three might have added depth to the research and have yielded further contributions. In contrast, the more holistic approach adopted in the research has opened up opportunities for collaboration both with other researchers and with industry. Since the research is broad, the literature review has addressed the various fields related to the vertical extension of buildings; however, a consequence is a lack of detail in some of those fields.

In this research, no deductive studies have been performed, even though deductive reasoning is a foundation stone of research. The main reason for adopting other lines of reasoning was to gain a better understanding of the topics involved through exploratory studies. Deductive reasoning requires the formulation of a hypothesis; however, the formulation of a hypothesis requires knowledge, which has to be acquired first.

6.2 Empirical studies

Study 1 has been the most significant and productive of the studies undertaken. It was reported in papers I and II, as well as contributing to paper IV. The IEA EBC Annex 56 project has given the author insight into how energy-efficient renovation projects are being implemented in other European countries. The country-specific context aside, proponents of renovation face many common challenges regardless of the country in which they operate. In paper I, the total yearly lifecycle costs of four concepts studied was presented; in this analysis it was assumed that the annual increase in energy costs is 0%. The researchers' argument at the time was that if the energy prices were stable and the real interest rate was low, it would yield an insignificant adjustment factor. In hindsight this was a mistake. Even a low increase in the district heating price and a low real interest rate would yield an adjustment factor of approximately 1.3. This is calculated with a district heating price increase of 1% and a real interest rate of 3%.Whilst an adjustment factor of that size would not have significantly changed the outcome of the results presented in paper 1, in another study, with different assumptions, it could have been decisive. In paper II, vertical extension of buildings was argued to be an enabler for energy-efficient renovation since a lifecycle analysis showed that just the low-energy plus vertical extension concept could be considered financially viable. Even though the analysis was based on a detailed case study, the argument might have gained strength if other cases could have been analysed in addition. Attempts were made to study the financial aspects of other vertical extension projects; unfortunately, these attempts failed to attract the input needed for a lifecycle analysis.

Study 2 was an exploratory study concerned with the current practice of stakeholder participation in densification projects; as such, interviews were chosen as the means for data gathering. A total of ten interviews were held with practitioners in the southwest part of Scania. The study could be considered representative of practices in the region; nonetheless, the study showed that the majority of initiatives involving stakeholder participation are led by its proponents. Moreover, the interviewees claimed that other practitioners worked differently in other regions, so it would be unwise to generalise for the country as a whole.

A similar discussion can be had regarding study 3. Four cases of the vertical extension of buildings were studied, all of which have been implemented or planned in large Swedish cities and were originally built during the *million homes programme*. With this in mind, and the limited number of cases studied, it would be similarly unwise to suggest that the findings presented in paper IV could be generalised. Other cases of vertical densification have been identified; but no data have been gathered.

Concluding remarks

This chapter has acted as an introspective review of the research and some of its strengths and weaknesses have been highlighted. The studies have in common that the amount of data gathered in the studies are a limiting factor; therefore, more studies are needed before conclusions can be generalised.

7.Conclusions

In this chapter, the final conclusions of the research and future research are presented. In the final conclusions, the research objectives are revisited and the research questions are answered. Lastly, two research projects and an idea for future research are presented.

7.1 Final conclusions

It has been shown from the analysis of policies and literature that the vertical extension of buildings is a relevant topic today and is linked to the three aspects of sustainability, namely environmental, economic and social performance. According to the literature, there are both positive and negative effects such as increases in efficiency and over population, stemming from the vertical extension of buildings.

The four research objectives have been addressed:

1. In all three studies, stakeholders involved in extending buildings vertically have been engaged through interviews and meetings.
2. In studies 1 and 3, cases where buildings have been extended vertically were identified and examined.
3. In the literature review, overlapping research fields were identified and examined.
4. A development process for the implementation of the vertical extension of buildings has been proposed and explained in study 3 and was reported on in paper IV.

The two research questions have been answered as follows.

RQ 1: How does the vertical extension of buildings impact sustainability?

As shown in papers I and II, the vertical extension of buildings can enable energy-efficient renovation; for instance, energy use by the building in study 1 was reduced by 65%. The vertical extension of buildings can also reduce the growth of the urban footprint, without occupying recreational spaces within city borders.

As shown in paper II, in regard to the building in study 1, the lifecycle analysis of the four renovation concepts showed that just the concept of low-energy plus vertical extension was financially viable. In paper IV, a few development decisions were presented as key for the implementation of vertical extension building projects, many of which have financial implications.

Some of the challenges to the vertical extension of buildings are related to the social aspect of sustainability, for example population density, access to services and gentrification. In paper III, stakeholder participation was highlighted as a tool which could be used to achieve more sustainable development.

RQ 2: Which are the main success factors to extending buildings vertically?

In study 3 several factors were identified as key for a successful implementation; however, all of them are case specific and therefore impact each project differently. Often the structural framework will need reinforcement, how much and how the reinforcement can be installed is fundamental for the success of the project. The added floors will need utilities, using existing shafts or using the reinforcement as installation space is beneficial. During production there are many aspects to consider, transportation, construction site and safety for example, these aspects have to be carefully considered before the procurement process, since building in a dense urban environment can be challenging. A high market demand is needed, since extending a building vertically is expensive and complicated. Because of the same reason, the size of the extension must be significant, it is more likely that a larger extension will be viable.

7.2 Future research

In order to further develop the knowledge of vertical extension of buildings additional studies have to be made which builds on what has been reported on during this research. Studies which builds on or falsifies the development process, from paper 4, would greatly benefit the diffusion of vertical extension of buildings. A process which highlights success factors and puts them in a real world context could be used by practitioners and research alike in order to better understand the implementation of vertical extension of buildings. In this research the links between vertical extension of buildings and sustainability have been studied; however, more research is needed from a variety of disciplines. Sustainable urban development is a complicated topic and input from disciplines such as architecture, sociology, psychology and ecology is needed. Even though a few of the links between vertical extension of buildings and sustainability have been highlighted in this research, it is only the tip of the iceberg.

7.2.1 My future research

In order to meet the 2050 policy targets and achieve a more sustainable development, the condition of the existing building stock will have to be addressed and steps taken to improve it. In this research, the vertical extension of buildings has been shown to be one possible improvement; however, there are many other solutions which also can be considered to lead to a sustainable development. Over the coming years I will continue to study sustainable urban development, but will focus on other methods than vertical extension of buildings. Whilst there are many methods for improving the existing building stock, two ideas for achieving more sustainable development will be investigated in future research, namely multi-active façades and building renovation on the district level.

The multi-active façades project started at the end of 2015. It is a two-year collaboration between Lund University (Division of Energy and Building Design and the Division of Construction Management) and NCC. The project, "Feasibility study of prefabricated multi-active façade elements for energy renovation of multi-family houses", is funded by *SBUF* and *Energimyndigheten*. It has a reference group made up of industry-based organisations: *Elementum Eco*, *Smart front*, *Nibe*, *Landskronahem* and *Paroc* among others. The idea behind the multi-active façade concept is to develop the concept of a "prefabricated multi-active façades". Similar concepts have been used to renovate buildings in Austria and Germany, but have not yet been implemented in Sweden. One of the largest challenges facing energy-efficient renovations today is the financial aspect, highlighted in papers I and II. The objective of the project is to determine if a multi-active façade concept could be financially viable. The façades are intended to integrate insulation, ventilation, heating and solar power into a prefabricated solution, hence the name multi-active façades. The project is expected to be finished during the summer of 2017.

The other research project is building renovation on the district level. Here, the focus is an IEA EBC Annex project and is a continuation of the Annex 56 project (see study 1). The project, "Cost-effective strategies to combine energy efficiency measures and renewable energy use in building renovation at district level", has the aim of studying renovation measures that reduce energy use and emissions on the district level. For example, historical buildings are challenging to renovate; however, there might be opportunities when it comes to district-wide renovation, such as improving district heating. Moreover, many buildings operate and maintain their own heating systems; whereas, a district heating system might be more beneficial. Similar arguments can be made for energy production and energy storage. The project has not started.

During the studies, a common theme was identified, namely a general lack of understanding of how renovation concepts can be compared and how the best concept can be chosen. During the research, methods for comparing concepts were identified, for example *Renobuild*, *Total concept* and *Lifecycle sustainability assessment*; as of yet, these have not been studied.

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Appended papers

Paper I

The paper was submitted to, and presented at, the 12th REHVA World Congress CLIMA 2016, 22-25 May, Aalborg, Denmark. This paper was written using the findings from study 1. As part of the IEA EBC Annex 56, case studies would provide examples of realised energy-efficient renovation projects. The case, from study 1, was the renovation of a multi-family building from 1971, which can be described as a typical building from the so called *million homes programme*. The factors analysed in this paper were: energy savings, lifecycle cost analysis, lifecycle assessment and co-benefits. Input was gathered from interviews and document analysis provided by the housing company and the contractor.

Paper II

The paper was submitted to, and presented at, the 12th REHVA World Congress CLIMA 2016, 22-25 May, Aalborg, Denmark. This paper was also written using the findings from study 1 and is a follow-up to paper I on the renovation plus vertical extension that the housing company decided to realise in the remaining five buildings. The main reason was to improve profitability from the first renovation. The method chosen for examining the renovation concept was a lifecycle analysis. The inputs for the analysis were gathered from interviews, with supporting documentation provided by the housing company and the contractor. In this paper, four concepts were developed which were analysed in order to find the most appropriate renovation concept.

Paper III

This paper was submitted to, and presented at, the 20th CIB World Building Congress 2016, 30 May to 3 June, Tampere, Finland. The paper was written in order to find the links between densification projects and stakeholder participation and is based on study 2. The paper's exploratory nature and focus required a qualitative method; therefore, an interview-based study was the chosen. The findings and analyses of study 2 were categorised into seven themes in this paper.

Paper IV

This paper is a manuscript soon to be submitted. The paper is based on the results from study 3, a multiple case study. In this paper the success factors for vertical extension of buildings are described using a development process. The author links the development process for the vertical extension of buildings to diffusion of innovation theory. The aim of the paper is to share knowledge and simplify the process of extending a building vertically.