Optimisation before growth

New property formations for a resource-efficient use of the existing building stock

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Optimisation before growth:
New property formations for a resource-efficient use of the existing building stock

Optimering framför tillväxt:
Nya fastighetsindelningar för ett resurseffektiv användande av det befintliga byggbeståndet

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Summary

The building industry accounts for around one third of the total energy use and GHG emissions in Sweden. Despite the implementation of energy efficiency measures focusing on new buildings, embodied impacts from material extraction, manufacturing, construction and maintenance have grown in significant proportions.

While cities like Stockholm are currently experiencing a strong demographic growth and a high pressure on the supply of new spaces and facilities for new residents, national environmental goals aim to reduce energy use and GHG emissions in the coming decades. For instance, the new Climate Act in Sweden expects the country to become carbon neutral by 2045 and the European Commission urges the decarbonisation of national building stocks by 2050.

The dual pressure of growth and environmental targets urges the exploration of alternatives for the supply and use of space. In fact, some sources indicate that many spaces remain unused during several hours a day/week and estimations show that most of the buildings that will be in use in 2050 have already been built today.

This study explores the potential for a resource-efficient use of space in the existing building stock in Stockholm, leading to a positive impact on the reduction of energy consumption and GHG emissions. The inquiry is conducted with a mixed methods approach in three sequential steps: the identification of relevant stakeholders, instruments and initiatives; the analysis of use of space in a sample of commercial spaces at the street level; and the formulation of strategies allowing an increase in their temporal and spatial capacity.

The study suggests that one way to optimise the use of space in existing buildings is to create new property rights. Specifically, it illustrates how merging commercial spaces on the street level through the constitution of 3D properties can increase the capacity to accommodate activities in space and time. Together with digitalisation and the development of new services based on sharing solutions, this opens up new possibilities for decreasing new construction and to absorb new demands for heated floor area.

Keywords: 3D properties, sharing solutions, building stock, use of space, resource-efficiency.
Sammanfattning

Bygg- och fastighetsindustrin står för ungefär en tredjedel av energiförbrukningen och växthusgasutsläppen i Sverige. Trots införandet av energieffektiviseringsåtgärder i nya byggnader har andelen inbyggda effekter från materialutvinning, tillverkning, konstruktion och underhåll växt anmärkningsvärt.

Städer som Stockholm upplever i nuläget en stark befolkningstillväxt och ett ökande tryck på tillförseln av nya utrymmen och tjänster för nya invånare, men nationella miljömål förespråkar en sänkning av energianvändning och växthusgasutsläpp under de kommande decennierna. Till exempel har Sveriges nya klimatstrategi som mål att landet kommer vara fossilfritt år 2045, och Europeiska Kommissionen uppmuntrar till utfasning av koldioxidutsläpp från ländernas byggnader innan år 2050.

De dubbla trycken från tillväxten och miljömålen uppmuntrar till utforskning av alternativa strategier för tillförseln och användandet av lokaler. Forskningen pekar på att många lokaler står oanvända under flera timmar per dag/vecka, och det har uppskattats att majoriteten av de utrymmen i användning år 2050 redan har byggts idag.

Denna studie undersöker potentialen för en resurseffektiv användningen av utrymmen i de existerande byggnaderna i Stockholm, med positiva effekter för energiförbrukningen och växthusgasutsläppen. Undersökningen utfördes med en blandning av metoder i tre steg: identifiering av relevanta intressenter, instrument och initiativ; en analys av användningen av utrymmena i ett urval av kommersiella lokaler på markplan; och en utformning av strategier som tillåter en ökning av utrymmenas temporala och rumsliga kapacitet.

Studien tyder på att ett sätt att optimera kapaciteten i existerande byggnader är att utforma nya fastighetsbildningar. Närmare bestämt illustrerar studien hur en sammanfogning av kommersiella lokaler på markplan genom införandet av 3D-fastighetsbildningar kan öka kapaciteten för olika aktiviteter i tid och rum. Tillsammans med digitalisering och utveckling av nya tjänster baserade på delningslösningar öppnar detta upp nya möjligheter för minskning av konstruktionen av nya byggnader och absorption av behovet av ny uppvärmd yta.

Nyckelord: 3D-fastighetsbildningar, delningslösningar, byggnader, användning av utrymmen, resurseffektivitet
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Abbreviations

BIM. Building Information Model
BRF. Bostadsrättsförening
EU. European Union
FFSRE. Forum For Sustainable Real Estate
GIS. Geographic Information System
GHG. Green house gas
HVAC. Heating, ventilation and air conditioning
IoT. Internet of Things
SNI. Svensk näringsgrensindelning. Swedish Standard Industrial classification.

Glossary

Bostadsrätt. Tenant-ownership apartment
Bostadsrättsförening. Housing association
Fastighetskontoret. Real Estate Office
Hyresrätt. Rental apartment
Lantmäteriet. Swedish Land Registry Authorities
Skatteverket. Swedish Tax Agency
1. Introduction

1.1 Background

1.1.1. URBAN GROWTH AND ENVIRONMENTAL TARGETS

In Sweden, the building industry accounts for 18% of GHG emissions, 31% of energy consumption and 31% waste in the country (Figure 1). The information campaign “Bygg klimatsmart”, suggests that the construction and real estate sectors need to actively transition towards more sustainable activities if climate targets are to be met (Bygg klimartsmart, n.d.). “Many people recycle, think twice before flying, avoid the private use cars… but how many even know that our houses are one of the worst polluters?” (idem), stresses the campaign.

The City of Stockholm approved a new City Plan in 2018 including several strategic guidelines to address the expected population growth (Stockholms stad, 2018). According to the plan projections, Stockholm will hit the million inhabitants mark by 2020, and if the current average rate of 15,000 new residents per year is maintained, the figure could reach 1.3 million by 2040 (idem, p.7). The City Plan sets out the target of providing “140,000 new homes by 2030” (idem, p.32), highlighting the potential for new urban developments that would add value to poorly exploited parts of the city (idem, p.26). Moreover, the Chamber of Commerce of Stockholm warns of an office space shortage in the city center (Stockholms Handelskammare, 2018). The report “Företagen larmar om kontorsbrist” —based on interviews with 200 businesses located in central Stockholm— considers the alleged shortage of office space as the main obstacle to growth, preventing businesses from recruiting new talent due to spatial constraints (idem, p.6). Office space is reportedly scarce, crowded and expensive, yet the location in central Stockholm is crucial for the interviewed businesses, to the point of considering to move to other European cities rather than to a suburban area (idem).

At the same time, the new Climate Act in Sweden —effective as of January 1st 2018—, expects the country to become carbon neutral by 2045 and even carbon negative thereafter (Swedish...
Government, 2017). The building industry will need to adapt to this challenge when supplying new facilities, infrastructure and housing. Furthermore, the EU’s new Energy Performance of Buildings Directive (EPBD) urges EU countries “to establish stronger long-term renovation strategies, aiming at decarbonising the national building stocks by 2050” (European Commission, n.d.). It is estimated that almost 75% of the existing building stock in Europe is energy inefficient (idem).

During the last decades, there have been significant reductions in energy consumption and environmental impact of buildings, focusing mainly on the operational phase through e.g. the integration of highly efficient envelopes and installations (Birgisdottir et al., 2017). In some countries the operational energy use has been reduced to less than one third over the last 25 years (EFKM, 2014). However, according to Birgisdottir et al., (2017, p.72) the impact from material extraction, manufacturing, construction and maintenance (i.e. embodied impact) is significant and is growing in proportion compared to the operational phase, stressing the need for a parallel work towards reducing embodied impacts.

To summarise, the construction industry uses a significant amount of energy and experiences a dual pressure of housing and office shortage. The need to become carbon neutral by 2045 urges to find alternatives to achieve these goals in the existing building stock.

1.1.2. THE BUILDING STOCK AS A RESOURCE

Buildings support activities and access to services for users and tenants, they represent economic assets for property owners and they constitute the image and quality of urban environments for the city. Kohler & Hassler (2002) highlight the relevance of “The building stock as a research object” referring to the economic, social and cultural value of buildings. The authors call for the development of long-term management indicators (idem, p.234) allowing to secure the preservation of qualities and value in existing buildings, as well as the assessment of the environmental impact related to their use. As described by Thuvander (2002, p.27) “the design and construction phase of a building is handled as a short-term project; in contrast, the management of a building is a long-lasting process”. Some studies indicate that the physical life of buildings exceeds their service life, and renovation is preferred over demolition (Thuvander et al. 2012, p.1189). Thus, once a building engages this “long-lasting process”, it becomes a resource for different actors that maintain and benefit from its value, considering that during its lifespan, a building often goes through different changes of management, ownership and use (idem).

However, data and measurements of properties are fragmented across different stakeholders, rely on the owner’s management interests (e.g. what to monitor) and are not necessarily accessible (privacy), which makes it difficult to collect as a basis for urban planning. Kohler & Hassler (2002, p.229) point out that lack of data on the building stock limits their study and description and therefore long term planning. Even today with advanced digital tools such as BIM (design model) and GIS (“real world” model), property owners and land registry authorities have limited descriptions of properties (e.g. 2D cadaster, 2D drawings) mainly due to cost and/or regulatory constraints (Isikdag & Zlatanova, 2009). According to El-mekawy et al. (2014, p.19), the amount of manual work and the inconvenience of collecting data from different sources and stakeholders are the main reasons why BIM is not widely used for existing buildings.
Thuvander (2002, p.31) stresses the link between the use of resources and the temporal aspects of building stocks, therefore advocating for the monitoring of time aspects to describe a building stock from an environmental perspective.

In Europe, buildings have a long lifespan and are renovated at a rate of 0.4 to 1.2% per year (European Commission, n.d.). This figure is around 0.6% for Swedish residential stock (Boverket, 2014, p.45) meaning that despite the remarkable progress in the development of environmentally friendly construction, the existing building stock will still represent a larger volume compared to future new buildings by the decarbonisation deadline of 2045 (UNEP SBCI, 2009). In fact, it is estimated that most of the buildings that will be in use in 2050 have already been built (idem, p.6). The European Commission (n.d.) estimates that improvements in existing buildings could potentially reduce the EU's total energy consumption by 5-6% and lower CO2 emissions by about 5%. However, according to Thuvander et al. (2012, p.1192), energy improvements alone are seldom the main motivation for initiating major renovations, which suggests that additional incentives are often required (e.g. social, cultural, economic).

To summarise, from a resource-efficiency perspective, the building stock can be considered as a man-made resource. Some authors highlight the importance to keep its value over time as the use and production of buildings has a considerable toll on the environment. Buildings change over time in use and it is crucial to collect data in order to plan for the long-term management.

1.1.3. URBANISATION AND RESOURCE EFFICIENCY

Resource efficiency is one of the seven flagship initiatives created by the European Commission as a long-term framework for the EU's growth strategy. The initiative aims to develop a “smart, inclusive and sustainable economy” (European Commission, 2016, p.8), and it outlines the structural and technological changes needed for it to be successfully implemented by 2050. “Improving buildings” (idem, p.53) is included in the roadmap to achieve a successful transition towards a resource efficient and sustainable economy. According to the European Commission, resource efficiency proposes “ways to decouple economic growth from resource use and environmental impact” (idem, p.7), and is defined as the use of the planet’s limited resources in a sustainable manner, producing “more value with fewer inputs”. (idem, p.8)

Drawing on the increased pressure caused by urbanisation processes on the demand for new construction, Höjer & Mjörnell (2018) propose a four-step principle that can lead to a more resource-efficient use of existing buildings (idem, p.5-6). Ranging from the lowest to highest use of energy and resources, the steps to supply space would be: a) reduce the demand for space; b) increase the activities per space unit; c) extensions and adaptation of existing buildings; d) new construction following the first two steps.

The authors (idem, p.2) stress the role of digitalisation in opening up unprecedented possibilities for the development of new services (e.g. sharing offices or homes, retail and online shopping, food deliveries, etc.) thus enabling new and more efficient ways of using spaces in buildings. According to Höjer & Mjörnell (idem), the main benefits of using existing buildings more efficiently as opposed to building new ones are: resource-efficiency in the construction industry can increase; energy use for heating and operation can be reduced; higher densities creates a better support for public transport; more intense use of building contributes to create vibrant urban environments.
With a categorisation of uses of interior space "density" and use in time, the authors illustrate the potential to accommodate more activities through sharing, considering the size of the space and the degree of use in time. The suggested categories are (idem, p.6):
- Spacious sparsely used: e.g. large rooms, low presence
- Dense sparsely used: e.g small rooms, low presence
- Spacious frequently used: e.g large rooms, high presence
- Dense frequently used: e.g small rooms, high presence

Energy performance in buildings is expressed in kWh/m². According to the authors, this measurement favours buildings with lower intensity of use and does not take into account the embodied impact of the construction (idem, p.4). Drawing on the idea that a reduction of the overall energy use in entire building stock is more relevant than the energy use per square meter (i.e. kWh/m²) (idem, p.9), the authors suggest the use of alternative measurements, such as energy use and GHG emissions per person or activity, instead of squared meter (idem).

Thus, Höjer & Mjörnell (idem, p.10) suggest a combination of the four-step principle, the categorisation of use of space and activity-based measurements together with digital tools and processes as a conceptual framework to decouple supply of space from new construction, leading to a reduced environmental impact. The authors encourage further research and empirical studies to explore different ways of implementing the ideas both from a policy and innovation perspective (2018, pp.8,10), which this study uses as a starting point and framework.

1.1.4. SHARING CITIES

In one of the sessions organised by the Forum for Sustainable Real Estate about circular economy and sharing solutions (Fastighetskontoret, 2016) Duncan McLaren —researcher in urban development— held a lecture on how the sharing economy is changing cities and urban development based on his research work (McLaren, 2016).

According to McLaren (2016), we co-create the cities and the economy by sharing urban environments and spaces. To him, the process of "urban commoning" —discussed in the work of David Harvey— is a helpful reminder that shared spaces are our commons as collective ownership and collective use. McLaren (2016) suggests that better sharing makes better cities as it makes it possible to live together in dense urban areas “[...] sharing is what makes cities work”, he adds. McLaren (2016) understands sharing as cultural and political, not simply economic. Thus, a sharing city should make sharing work at all levels, i.e. not only in terms of resource-efficiency but also regarding equity and fairness. In a sharing cities paradigm, there is a shift from socio-cultural to intermediated sharing. McLaren (2016) refers to socio-cultural sharing as the traditional way of "reciprocal altruism" e.g. in families or communities. However, thanks to technological innovation and digitalisation (e.g. mobile identity and payment services, internet of things [IoT]) new forms of "intermediated sharing" have appeared together with new norms and values, extending sharing to strangers (idem). Different kinds of intermediaries other than commercial ones such as civic, charitable and communal can be identified (idem).

McLaren (2016) points out that “we get value and well-being out of the services that products give us and not by the products themselves” which encourages a sharing approach rather than that of ownership. Sharing is disrupting norms and behaviours e.g. the way we work, live, travel, learn, etc. (idem). Thus, today we see forms of intermediated sharing illustrated by offices with no desks (e.g. hotdesking, coworking), hospitals with no beds (e.g. virtual healthcare), education without classrooms.
(e.g. online courses, applications), the world’s largest movie distributor with no cinemas (Netflix), landlords with no properties (Airbnb), taxi companies with no cars (Uber), and so on (idem).

McLaren (2016) suggests some benefits from a sharing economy: “cut demand for new products; release the value in things we already made that are not used very intensively, where an intermediator captures a slice of value in every transaction; save energy, reduce waste and emissions; if services don’t depend on ownership, it might be easier to guarantee access for all”. In this understanding, sharing has the potential to improve resource-efficiency, curb consumer demand, maximising value of properties democratising access to services. Moreover, McLaren (2016) emphasizes that the sharing economy has the power to undermine the value of consuming goods as a part of our identity.

However, in terms of energy use, there might be rebound effects (idem). For example, the savings we make are still used in other energy intensive activities (e.g. savings through AirBnB spent on flying to the destination), making environmental benefits less obvious (idem). They depend on the context and on how sharing solutions are designed. These shortcomings can be overcome "as long as we identify and pursue the prospects of developing a sharing society in political and cultural ways", stresses McLaren (2016).

McLaren (2016) formulates various practical recommendations for the creation of sharing solutions by: prioritising exchanges with other sharing organisations (e.g. support, investments, procurement); direct the attention to "urban commons" such as public spaces and utilities; design solutions that build trust and social capital; empower users to protect their civil liberties and privacy; experiment with regulations and incentives and provide access for all. (idem). The development of new services and forms of management is therefore a crucial requirement for a successful implementation.

1.2 Aim

This research project aims to explore the potential for a resource-efficient use of space in the existing building stock in Stockholm, leading to a positive impact on the reduction of energy consumption and GHG emissions.

1.3 Scope

This study focuses on the city of Stockholm and goes from a general to a specific context. The general level allows an anchoring of the inquiry to current ideas and initiatives in the field, building up a framework to identify relevant stakeholders as well as gaps, limitations and opportunities for further development of resource-efficient use of space in existing buildings. The specific level grounds the inquiry in a concrete context, which allows the collection of measurable and quantifiable data. The analysis of the obtained data provides indicators and criteria to propose practical ways to develop/implement solutions for an efficient use of space in a concrete case.

The study consists of the following three steps:

- First step, based on the four-step principle presented by Höjer & Mjörnell (2018) a qualitative review of the current state of the discussion around efficient use of space in existing buildings in Stockholm is performed. This allows an identification of relevant planning instruments, initiatives and stakeholders contributing to a reduction of demand for space, and/or efficient distribution of activities in time and space.
- Second step, definition and quantitative survey of a concrete sample of the building stock in order to analyse indicators of use of properties in space and time. The objective is to see how efficiently space is used and find ways to reorganise the patterns of use of space (e.g. activities, ownership, opening hours) in a way that existing properties could absorb new demand for space, while offering suitable alternatives to decrease the demand for new construction.

- Third step. Based on the previous findings, formulation of strategies that allow a reconfiguration of patterns of use of space in order increase the spatial and temporal capacity to accommodate activities in existing buildings.

How this should contribute to both a resource-efficient use of the existing building stock and to meet environmental goals is discussed and motivated.

1.4 Research questions

The extent of the inquiry will be delimited by three research questions, which can be understood as sequential steps of the inquiry. They account for each of the outlined steps and feed the subsequent one with the previous findings.

1- What is the current approach to resource-efficient use of space (land and buildings) in Stockholm? The objective of this question is to identify gaps and opportunities for further development, building upon current ideas and initiatives. The inquiry also aims to identify how the efficiency of use of space is problematised by the existing stakeholders, if at all. A final goal is to identify relevant elements for the next step of the inquiry.

2 - What patterns of use of space can be identified in a representative sample of the existing building stock, with respect to their potential for more efficient use of space? The objective of this question is to analyse and compare the temporal and spatial patterns of use in a range of properties, based on quantitative data collected from a dense and consolidated part of the city. These findings then form the basis for the next stage of the study.

3 - How can the identified patterns of use of space be reconfigured in order to offer a suitable basis for more efficient use of space? The third question aims to outline a proposal for the reconfiguration of temporal and spatial patterns in order to improve the capacity of existing buildings, and thereby contribute to the achievement of environmental goals.
2. Methods and data

The explorative nature of the aim of this study led to choose a mixed methods approach in order to converge, illustrate and develop the results of the different steps of the inquiry and to create links between general and specific components.

![Figure 2. Explorative process: expanding and triangulating the network of keywords and concepts. Source: Own representation](image)

The explorative process began with the expansion of keywords from the aim of the research, based on concepts and further areas of inquiry outlined in Höjer & Mjörnell (2018). The combination of search keywords “use of space”, “building stock” and “resource efficiency” expanded the spectrum of related fields, previous research and authors in non-linear multidirectional ways, as represented in Figure 2. This allowed to see and to evaluate what connections were missing or could be established, based on the aim of the study and the first research question (see sections 1.2, 1.4).

For instance, one key reflection at this stage was about the relationship between land use and use of space in existing buildings. It led to investigate the planning process behind the creation and management of existing buildings. How are the spaces attributed/supplied? Who regulates the functions? How to plan for the existing? These interrogations connected keywords and brought in property rights and associated stakeholders to the network of the inquiry.
By contextualizing this exploration in Stockholm, specific stakeholders, initiatives and sources of data joined the keyword network and some redundancies were identified, i.e. many keywords related to each other in several ways. This constituted the structure and elaboration of the results in the first research question (see section 1.4), which allowed the definition of the criteria for the next steps of the inquiry (i.e. indicators to be surveyed) and provided references of similar quantitative approaches for its analysis, based on previous research on building stocks. Thus, different connections could be created, informed, questioned, converged thanks to the mixed methods approach.

Different authors define mixed methods research as the one combining quantitative and qualitative approaches and techniques in a single study (e.g. Johnson & Onwuegbuzie, 2004, p.17). Based on the definitions provided in Greene et al. (1989, p.259), the main relevant purposes of mixed methods in this study are to mutually inform, corroborate and enhance the results of the different steps and methods. Schoonenboom & Johnson (2017, p.113) distinguish between the parallel and sequential timing of the methods in mixed approaches. In “sequential”, a qualitative component precedes a quantitative component (idem). Thus, the study is planned in a sequential way and is open to "emergent“ components (see section 2.3) during the process of the inquiry.

Figure 3 shows the sequential steps of the inquiry and how the findings of one step lead to the subsequent one. In (1), the network of keywords (see Figure 2) establishes the search frame for both relevant literature and key informants for interviews. This allowed the identification of indicators and sources of data used in (2) for a quantitative survey of a sample of commercial spaces as to their potential for a more efficient use of space. In (3) a proposal suggesting ways to fill gaps and enhance the identified areas of optimization is illustrated based on the analysis of findings in (2). The illustrations were used as a starting point for a discussion with experts in the field, able to estimate its suitability and relevance.

2.1. LITERATURE OVERVIEW AND INTERVIEWS

For the first step (research question), qualitative methods are used in order to describe and to characterise the current approach to resource-efficient use of space in existing buildings in Stockholm. The literature review and interviews contributed to draw out sources of data and ways to study building stocks, which allowed the identification of relevant quantitative indicators. Their analysis was then carried out by examining connections between them.
Literature review. Relevant literature was identified through references and authors within the keyword network (see Figure 2). Key documents were considered those covering a wide range of aspects regarding “use of space” and “resource efficiency” in a comprehensive way. Their relation to the context of Stockholm and to the four-step principle presented in Höjer & Mjörnell (2018) provided possible answers to the research questions. Specifically, the reports associated to the FFSRE encompass sharing solutions, efficient use of space and management of properties; previous research on building stocks provide references of quantitative approaches as well as current knowledge gaps; literature about property rights and 3D properties explains their origin, purposes and definitions. Thus, the literature review discusses a selection of research papers, reports and policy documents focusing on: a) land use in densely built urban areas with mix of uses and functions, b) management of existing buildings, c) level of awareness on efficient use of space in the real estate sector and environmental relevance of sharing solutions. This allowed the identification of relevant planning instruments, initiatives and stakeholders. The literature review was also useful to identify topics for guiding the discussions in the interviews.

Translated documents. Most of the documentation was found in Swedish and summarised in English with own translations. Key arguments and concepts have been verified in peer-reviews and advice from native speakers. The translations were considered to be good enough for their purpose.

Interviews. Semi-structured interviews were conducted where specific literature or other sources of data were not available or accessible. It appeared to be the case when looking into “use of space” in Stockholm, as both privacy issues and limited published/measured data represented an obstacle. This made the interviewees key informants in the inquiry, considering the scope of this study. Thus, their insights and arguments are used as a reference in later stages of the inquiry. According to Given (2008, p.810), in semi-structured interviews the researcher has control over the topic while leaving open the range of responses to the questions. This was considered suitable for an exploratory approach. A detailed description of topics/questions discussed during the interviews can be found in Appendix 1.

Treatment of data. The interviews were recorded in order to retain a higher degree of accuracy and fidelity to the reasoning of the interviewees (Given, 2008, p.40). The recordings were done with the previous consent of the participants, who were aware of the purpose of the research. The interviews were transcribed and summarised as a part of this report. The data has been anonymised and the original recordings are protected from distribution to third parties.

During the process of the inquiry five interviewees were selected:

- Expert Y has carried out extensive research on 3D properties since its introduction in Sweden, touching upon purposes, planning processes, and representation issues amongst other related topics. Expert Y is highly knowledgeable on property formations and the current state of the research in the Swedish context, which provided insights for the analysis of use of space and connected to other key sources of information.

- Analyst Z has extensive professional experience in the field of real estate analysis in Stockholm and has worked with the development of 3D properties since their introduction in Sweden. Analyst Z provides highly valuable insights regarding market trends in Stockholm, specifically on the type of properties that are currently experiencing a shift in management needs and the way they are used.
- Consultant Z currently leads research on sharing solutions from a sustainable development perspective in the Swedish context. Consultant Z's work highlights technological and societal changes necessary to obtain environmental benefits from sharing solutions, which are useful to evaluate results of the third research question (see section 1.4).

- Two sustainability managers (hereafter referred to as Manager A and Manager B) who collaborate with property owners in Stockholm (hereafter referred to as Company A and Company B) were interviewed. Among other aspects of sustainability, Manager A and Manager B currently study sharing solutions as a way to develop their real estate portfolio in more efficient and sustainable ways. That specific part of their work focuses on how more flexible ways of making their properties available can encompass both economic and environmental aspects. The same set of topics was used in both interviews in order to be able to compare their approaches.

Property owners are key actors in the way that buildings are used and managed (property rights) (Julstad & Ericsson, 2001). They are crucial stakeholders for introducing changes for a more efficient use of the properties. The purpose of these interviews is to gain their insights regarding barriers, opportunities and trends for an efficient use of space.

Company A and Company B own a large real estate portfolio consisting of non-residential properties. They have taken part in the Forum for Sustainable Real Estate organised by the City of Stockholm and are among property owners in Stockholm actively investigating the benefits of an efficient use of space in non-residential programs (e.g. offices, schools), where a higher rate of vacancy suggests a potential for optimisation (Fastighetskontoret, n.d.).

2.2 SPREADSHEET AND ANALYSIS OF HANTVERKARGATAN

In the second step (research question), quantitative methods are used to measure and compare the use of space in time and area. This is done by defining a representative sample of a part of the building stock in Stockholm. Based on it, data sources are identified and data is collected in a spreadsheet. The aim is to identify the potential for more efficient use of space based on a current situation.

The analysis of the data was done by establishing links between different indicators and finding maximum/minimum, average and range of total or segmented values in Excel. Data sources used are open source. Otherwise, the information was provided upon request for the purpose of this study or only used for reference (see list in appendix).

The method used for collecting and analysing data is inspired by previous studies of buildings stocks. Aksözen et al. (2017) identify patterns that have an influence on the lifespan of a specific building stock through the collection and “reconstitution” of different layers of information on buildings. Mata et al. (2014) discuss “sample buildings” and “archetypes” as a way to describe building stocks (idem, p. 270). They use it to describe energy performance in entire building stocks in Europe, through the segmentation, characterisation, quantification and validation of collected data (idem, p.272).

Österbring et al. (2017) study renovation needs and potential improvements of energy performance in multi-family buildings in Gothenburg. Their study uses a “space and context” specific approach, that combines building specific information such as ownership, location and energy performance (idem, p. 697).
DEFINITION OF THE SAMPLE

The criteria for the selection of a representative sample of the building stock for this study draws on the background and research questions (see section 1.4), including: a) mixed-use dense area of Stockholm; b) be representative—as opposed to unique—i.e. the findings will be relevant in a broader urban scale; c) the extent of the sample should allow to capture a wide range of properties and activities and provide enough data to compare the different cases. The “sampling” of building stocks had been previously carried out by e.g. Theodoridou et al. (2011, p.2423). Samples of residential building stocks in Greek cities were used to describe energy use through a statistical analysis on tenure, building characteristics and residents’ profile (idem.)

For the present study, a street rather than an urban block was considered as a more appropriate delimitation for this purpose. The definition of the sample was narrowed down by location and type of property.

Location. Google Maps turned out to be an interesting tool to scan potential locations. In fact, the yellow/light orange tones used in their maps designate “areas of interest” (Figure 4). According to Google (n.d.), “We determine “areas of interest” with an algorithmic process that allows us to highlight the areas with the highest concentration of restaurants, bars and shops”. This can be interpreted as intensive mix and land use in urban contexts. Moreover, it would make the results comparable and transferrable to other “areas of interest”.

Type of properties. In the land registry, properties are classified by taxation code, a 3-digit number that describes the main purpose (use). Table 1 provides an overview of the composition of the building stock in the municipality of Stockholm by taxation code.

In terms of area, the 300 series “Hyreshusenheter“ is the most important type of property in Stockholm municipality. According to Skatteverket (n.d.), the 300 series includes several categories: land plot (310), housing (320), housing and commercial space (321), hotel or restaurant (322), office/commercial space (325).
The code 321 is the most common type of property in Stockholm (see Table 2). It designates properties with both housing and commercial spaces within the same building and it accounts for 45.7% of the total area in the series 300. A well-functioning strategy for this kind of property (321) could be scaled up to other parts of the city, offering thus a variety of geographic locations.

Table 1. Overview of property types in the municipality of Stockholm by taxation codes, as of 2018
Source: Lantmäteriet

<table>
<thead>
<tr>
<th>Taxation code</th>
<th>Count</th>
<th>Area (m²)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Lantbruksenheter</td>
<td>6</td>
<td>25'812'930</td>
<td>12.8</td>
</tr>
<tr>
<td>200 Småhusenheter</td>
<td>42'510</td>
<td>66'451'372</td>
<td>33.0</td>
</tr>
<tr>
<td>300 Hyreshusenhet</td>
<td>12'967</td>
<td>68'092'880</td>
<td>33.8</td>
</tr>
<tr>
<td>400 Industrienheter</td>
<td>2'583</td>
<td>29'289'410</td>
<td>14.5</td>
</tr>
<tr>
<td>500 Ägarlägenhetsenhet</td>
<td>16</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>700 Elproduktionenhet</td>
<td>2</td>
<td>114'527</td>
<td>0.1</td>
</tr>
<tr>
<td>800 Specialenhet</td>
<td>1'894</td>
<td>11'670'075</td>
<td>5.8</td>
</tr>
<tr>
<td>Total</td>
<td>59'978</td>
<td>201'431'194</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The code 321 is the most common type of property in Stockholm (see Table 2). It designates properties with both housing and commercial spaces within the same building and it accounts for 45.7% of the total area in the series 300. A well-functioning strategy for this kind of property (321) could be scaled up to other parts of the city, offering thus a variety of geographic locations.

Hantverkargatan. Located in the central district of Kungsholmen (Stockholm), Hantverkargatan fulfilled the criteria and was finally picked for practical reasons among other qualified options (e.g. Åsögatan, Nybrogatan). The street is included as an “area of interest” in Google Maps and it is located in a dense and consolidated part of the city. Most of the properties date back between 1880 to 1920 (see appendix). The majority of properties in the street correspond to the code 321. The properties create a spatial continuity along the street (as opposed to e.g. office buildings) and single results are comparable (similar management, use, tax rules).

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Table 2.1. Area of type code 321 in proportion to 300 series
Source: Lantmäteriet (2018)

<table>
<thead>
<tr>
<th>Taxation code</th>
<th>Area (m²)</th>
<th>% of total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series 300</td>
<td>68'092'880</td>
<td>100</td>
</tr>
<tr>
<td>Code 321</td>
<td>31'101'624</td>
<td>45.7</td>
</tr>
</tbody>
</table>

Table 2.2. Breakdown of areas in type code 321.
Source: Lantmäteriet (2018)

<table>
<thead>
<tr>
<th>Use</th>
<th>Area (m²)</th>
<th>% of total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>25'682'053</td>
<td>82.6</td>
</tr>
<tr>
<td>Commercial</td>
<td>5'419'571</td>
<td>17.4</td>
</tr>
</tbody>
</table>
In order to limit the amount of data and scope of the analysis, only the commercial parts on the street level are analysed, given the better access for surveys and data. Furthermore the immediate relationship with public space and urban environments provides an interesting perspective to discuss the impact of use of a more efficient use space. Figure 5 highlights the final selection of analysed properties.

**SPREADSHEET**

The collected data from the properties along Hantverkargatan was entered in a spreadsheet (see Appendix 2). This allows to register, compare, filter and aggregate results in different categories, as well as to identify/visualise patterns and indicators. Moreover, it establishes a basis for an analysis in terms of resource-efficiency.

Each commercial space on the street level in the selected properties represents an entry in the spreadsheet. Five categories were defined according to the available and accessible data, with the aim of providing a description of the sample in terms of location, technical aspects, management and use in space and time (see further details below).

The data sources consist of official records (e.g. Land registry, annual reports of housing associations), municipal and national open data platforms (e.g. Geoarkivet, Riksantikvarieämbetet), online services (e.g. hitta.se) and businesses’ websites. A field survey of the whole street was carried out in order to verify inconsistencies or missing data. It consisted of a photographic register of all the opening hours and names of the actual businesses or activities present and active in the street level.

![Photographic survey of opening hours in Hantverkargatan](image)

*Figure 6. Photographic survey of opening hours in Hantverkargatan
Source: Own pictures from field survey*
INDICATORS

The following tables provide a detailed description of the surveyed indicators and their purpose.

**Location.** Geographic location of the commercial spaces on the street, defined by official nomenclature and street address.

Table 2.3. Location indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Data source</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>The same property can have different addresses but the management and ownership is the same, as opposed to other systems where the address matches property units. In Sweden, the physical address by street name has rather spatial orientation purposes, with even/odd numbers assigned to one side of the street.</td>
<td>Geoarkivet</td>
<td>Text</td>
</tr>
<tr>
<td>Kvarternamn</td>
<td>Official designation of the property in the Swedish land registry system. In Sweden, each urban block has a name and the properties of which it is composed are assigned a number. It represents the land and constructions attached to a property and it is different from the street address. All the data in the land registry is associated to this nomenclature. E.g. &quot;Fikonträdet 18&quot; designates the real property located in the number 18 of the urban block &quot;Fikonträdet&quot;. This property for instance has five different addresses: Hantverkargatan 36, 36A, 38, 38A, 40 and Pilgatan 24</td>
<td>Lantmäteriet</td>
<td>Text</td>
</tr>
</tbody>
</table>

**Buildings.** Describes technical aspects and features of the properties having an influence on the use of the space, such as:

Table 2.4. Building indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Data source</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of building</td>
<td>Year when the building was completed. It allows to have an understanding of how long has the building been “used” and get a sense of the lifespan. Furthermore, technical/physical constrains such as HVAC installations and other physical properties (e.g. wall thickness, materials) can be assumed from the building’s age (typology).</td>
<td>Riksantikvarieämbetet</td>
<td>Year of completion</td>
</tr>
<tr>
<td>Heritage classification</td>
<td>In Sweden, buildings are classified in different categories according to their estimated cultural and historical value. This classification entails different levels of protection and it can restrict modifications in use and architecture. The categories used in this study are: Blue: Particularly high cultural value. It is the highest classification; Green: Particularly valuable in terms of historical, cultural, environmental or artistic qualities; Yellow: Positive impact on the image of the city and/or of a certain cultural value; Gray: Property with constructions that do not fit in the above categories.</td>
<td>Stadsmuseets kulturhistoriska klassificering (Stockholms stad, 2016)</td>
<td>Green, blue, yellow, grey. (text)</td>
</tr>
<tr>
<td>Area of commercial space</td>
<td>Size of each commercial space in sqm. Some areas were deduced (assumed) based on empirical reconstructions of interior spaces (facade length, typical depth) on a scaled base map, together with accurate information on property boundaries and building footprint.</td>
<td>Lantmäteriet, Annual reports, own estimation</td>
<td>m2</td>
</tr>
</tbody>
</table>
Management. Identification and characterisation of main stakeholders involved in the use and management of the space, including:

Table 2.5. Management indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Data source</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenant</td>
<td>Name of the business using the space. It is in charge of the management of the leased space regarding its use, organisation and image.</td>
<td>Business website, field survey.</td>
<td>Business name (text)</td>
</tr>
<tr>
<td>Owner</td>
<td>Name of the owner of the property, responsible for the management and subject to the payment of taxes.</td>
<td>Lantmäteriet</td>
<td>Name</td>
</tr>
<tr>
<td>Type of owner</td>
<td>Bostadsrätt / Hyresrätt, determines different management expertise, resources, BRF, company, association, private person.</td>
<td>Lantmäteriet</td>
<td>Text</td>
</tr>
<tr>
<td>Number of properties</td>
<td>How many properties does the same owner have in other parts of the city, interpreted as the capacity to supply space.</td>
<td>Lantmäteriet</td>
<td>Number</td>
</tr>
<tr>
<td>Taxation code (property type)</td>
<td>Classification of the property for taxation purposes by the Swedish Tax Agency. Taxation has actually been one of the main drivers for new property formations (e.g. 3D properties) which involves changes in ownership and management, resulting in a significant impact on the use of space</td>
<td>Lantmäteriet</td>
<td>Code</td>
</tr>
</tbody>
</table>

Use. Current activities and purpose of the commercial spaces.

Table 2.6. Use indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Data source</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNI (Swedish Standard Industrial classification)</td>
<td>SNI is a 5-digit code assigned to every registered company or association, which describes the domain or industry related to the company's activity. E.g. 56100 - Restaurant. It is used for statistical and administrative purposes by SCB, and Tax Agency among others (SCB, n.d.). It allows to identify clusters of activities belonging to the same field, which could be a basis for establishing common features and sharing solutions (e.g. shared equipments).</td>
<td>SCB</td>
<td>Code</td>
</tr>
<tr>
<td>Number of locations</td>
<td>The number of locations of the business, i.e. whether the business has other stores/offices in different parts of the city/country. It can be interpreted as demand for space, i.e. how much area does the business use in the city, which kind of businesses and activities are part of larger network.</td>
<td>Business website</td>
<td>Number</td>
</tr>
<tr>
<td>Age of business</td>
<td>Year of establishment of a business, can be useful to see which businesses/activities have been created in relation to important technological milestones that have changed business models through digitalization (online shopping, smartphones, consulting). Age of businesses is analysed in different year groups, where 2000 and 2010 are considered benchmark for widespread use of internet and smartphones respectively.</td>
<td>Business website</td>
<td>Number</td>
</tr>
</tbody>
</table>
According to Schoonenboom & Johnson (2017, p.122) unforeseen components can appear during the course of a mixed methods research and this can be planned or not, based on the certainty of the expected results. The third step of the inquiry falls into this category, as its results build upon the results of previous steps. Thus, the answer to the third research question is elaborated through illustrations based on previous findings and corroborated with an “open” section of the interviews with real estate and sustainable consumption experts. In this open section, the interviewees give feedback on the relevance, shortcomings and potentials of a proposal.

### 2.4 LIMITATIONS

The interviews were carried out in English with non native speakers. Although the communication was very clear and fluent, the different levels of proficiency might have prevented the interviewees from expressing or describing some potentially relevant details (e.g. technical) and the interviewer from guaranteeing the highest fidelity in the summaries and transcriptions.
The spreadsheet and collection of data was inspired by previous studies on related fields (building stocks) and it was considered good enough for the scope of this inquiry. However, advanced knowledge on statistical analysis and procedures would have probably helped to simply or to add other indicators. Additional input from stakeholders in the design of the spreadsheet and selection of indicators through e.g. a workshop would have maybe led to a different characterisation of the use of space.

The level of accuracy and detail of this study does not intend to account for its feasibility but rather to illustrate and discuss possible developments for a more efficient use of space in existing buildings, based on previous research and new findings. Around 20% of the data on floor areas was estimated in order give a better consistency to the analysis. Furthermore, since architectural drawings of the buildings were not a part of the analysis, the provided floor areas are interpreted as “total floor area”, i.e. including interior and exterior walls, without any further breakdown. The illustrations in section 3.3 do not take into account technical constraints.
3. Results

3.1. Towards a resource-efficient building stock

This section presents the findings of the first research question. This first step of the inquiry shows that there has been growing interest and initiatives in resource-efficiency and sharing solutions from both the public and private sectors in Stockholm, driven by both environmental targets and market trends (Fastighetskontoret, n.d.). Property rights play a crucial role as they determine the way spaces are used and managed, as well as the involvement of different stakeholders (e.g. in mix of activities, financing). In Sweden, 3D properties are a relatively new yet under-utilised type of property formation allowing to subdivide ownership in existing properties (Lantmäteriet, 2015). This represents an interesting possibility to reconfigure the management and use of parts of the existing building stock and from a resource-efficiency perspective, it opens up opportunities for the development of sharing solutions.

In Stockholm City, the Real Estate Office has promoted resource efficiency and sharing solutions through the Forum for Sustainable Real Estate and with the participation on research projects. The members of the forum estimate that the regulatory frameworks are not adapted for the development of sharing solutions and they are not sure about the actual demand from tenants (Fastighetskontoret, n.d.). Property owners feel pressure from both market and environmental targets and are looking for new ways to adapt their business models by developing new services based on digitalisation, focusing on sharing solutions.

3.1.1. PROPERTY RIGHTS AND USE OF BUILDINGS

Property rights define the ownership of land and buildings, which is a determining factor for later use and management (Julstad & Ericsson, 2001, p.175). In fact, one of the main concerns of the members of the Forum for Sustainable Real State (FFSRE) was the rigidity of real estate both spatially and legally (i.e existing space and regulatory framework) which according to them, does not support the flexibility required for a resource-efficient use (e.g. sharing solutions) (Fastighetskontoret, n.d.). In Sweden, a traditional property is delimited by an area (2D) that defines the ownership of land and objects attached to it. As explained in Julstad & Ericsson (2001, p.177):

"In theory, traditional (2D) ownership of real property is considered as reaching to the centre of the earth and upwards into the sky, but in practice only as far as it is reasonably possible to use [...]. No one except the property owner is entitled to use the space above or below ground for the construction of different facilities, unless given this right. The traditional property is thus only two-dimensionally delimited, but with a three-dimensional extent".

The use of the properties by other parties different than the owner is traditionally regulated by agreements such as the establishment of joint facilities (e.g. common parking space used by different owners), granting easements (e.g. pipeline going through someone’s property) and different kinds of leaseholds (e.g. rental contract) (Paulsson, 2012, p.197). However, the increasing pressure on land use in dense urban areas, has led to the need to create mixed-use projects which in turn require different financial sources and managerial expertise (Sveriges riksdag, 2003). As a response to the shortcomings of ownership rights associated with traditional (2D) properties, the so-called 3D properties were introduced in Sweden in 2004 (idem). As motivated in the governmental inquiries
preceding the entry into force of the law, in urban areas, where land is scarce and more intensively used—different activities and infrastructure need to be accommodated—the different stakeholders often would prefer to divide parts of their property so they can be owned and managed separately (idem, p.31). The text cites different examples of 3D situations: bridges and tunnels crossing several properties that are used for a completely different function, or bus and railway stations integrated with retail, shops, housing or offices (idem). The combination of a lack of land for new construction, infrastructure projects and urban growth pushes new developments to the spaces above or below existing properties (idem, p.32) (e.g. housing above existing railways tracks, underground parking facilities or emergency shelters). According to the law text, one clear example of the need for the division of ownership and management of a property is the case of buildings owned by housing associations (bostadsrättssägande) that rent out commercial spaces on the street level (idem). The housing association is the landlord for both housing and commercial uses. However, the latter is often perceived as a strange element to the property and an economic risk, since it demands special expertise for its management which the association does not always have (idem). Thus the commercial space can become a burden for the association, yet it is crucial for the quality of urban environments in terms of liveability, convenience, safety, among many others. In legal terms, Paulsson (2012, p.198) characterises 3D property as follows:

"The Swedish 3D property is defined as a property unit, which in its entirety is delimited both horizontally and vertically (Swedish Land Code, Chap. 1, s.1a). The 3D property units that are formed must relate to a built construction or other facility. The property unit does not have to consist of a whole building or facility, but can comprise only a part of it. It can be used to delimit and separate different facilities or floors within a building or in the ground also in depth and height. The Swedish 3D property may also extend over or under several ground parcels, and is thus not bound to be located within one two-dimensionally delimited property. The 3D property units are thus independent units with unique registration numbers and are independent from the land parcel".

The Swedish Land Registry Authorities (Lantmäteriet, 2015), highlight two main reasons to create 3D properties. One is to achieve a more effective management e.g. a residential property manager detaches commercial uses such as retail that require a different professional expertise. Another
reason is to have easier access to loans in the case of mixed-use developments where two or more shareholders are involved (idem).

Based on different authors, Paulsson (2012, p.196) points out the relevance of 3D properties as a tool to rationally manage land, buildings and other structures in dense urban environments, as well as to provide solutions to different actors that use spaces in different ways (e.g. retail and housing). However, only few configurations of this type have been created since the introduction of 3D properties in Sweden. According to latest figures provided by the Swedish cadastral authorities in 2018 (Table 3), there are around 300 units in Stockholm (including infrastructure such as tunnels and bridges). Thus, single ownership and management through 2D properties remain by far the main type of property in Stockholm.

Table 3. Type and number of 3D properties in the city of Stockholm as of 2018. Source: Lantmäteriet

<table>
<thead>
<tr>
<th>Type of 3D property</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergrum (ex. Deep geological repository)</td>
<td>12</td>
</tr>
<tr>
<td>Bro (Bridge)</td>
<td>1</td>
</tr>
<tr>
<td>Byggand (Building)</td>
<td>255</td>
</tr>
<tr>
<td>Tunnel (Tunnel)</td>
<td>20</td>
</tr>
<tr>
<td>Övrig anläggning (other facility)</td>
<td>2</td>
</tr>
<tr>
<td>Ägarlägenhet (condominium)</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total 2018</strong></td>
<td><strong>306</strong></td>
</tr>
</tbody>
</table>

In the past few years, however, the demand for 3D property formations has been increasing (see section 3.3.1), especially among housing buildings owned by Bostadsrättsföreningar (housing associations) with commercial spaces in the ground floor. In a study carried out in 2017 (Smeder & Mardi, 2017), tax reasons were pointed out as the main driver for the formation of 3D properties. In fact, with the new tax regulations introduced in Sweden in 2015 (idem, p.15), housing associations (BRF) and its members are subject to harder tax rules if the commercial space represents more than 40% of the taxable value of the property (idem). According to the study, some BRF even argued that it was considered as a strategy to increase the value of the apartments and to reduce the economic risk of vacant commercial space (idem, p.73).

Box 1. Integration of 3D properties in the land registry

According to (van der Molen, 2003, p.387-389), the main purpose of the cadaster (land registry) is the implementation of land policy instruments by supporting: a) land tenure security i.e. clear and legally binding delimitation of property boundaries; b) regulation of land market, i.e. transfer of property rights, mortgaging; c) land use planning, i.e. development and management of land; d) land taxation, i.e. information on land ownership and value. Van der Molen (idem, pp.389-391) discusses different forms of occurrence of “multi-use” of land and the need for including these informations in the land registry, as multi-use of land creates “3d situations” that might involve a separation of real rights from legal objects, challenging the way informations are included in the cadaster. Thus, he categorises multi-use of land on ground level, above surface, sub surface and time dependent. (idem).
Besides administrative complexities and costs, the formation of 3D properties entails also technical problems. For example, in order to have as few easements and servitudes as possible, it might be required to adapt existing buildings (Smeder & Mardi, 2017, p.71). Furthermore, the land registry in Sweden only supports 2D representations of properties and the location and extent of 3D properties are only based on text descriptions (El-mekawy et al., 2014, p.23), making the exact representation their boundaries inaccurate. According to El-mekawy et al. (idem), it is therefore urgent to implement a 3D cadaster in order to improve land taxation and to support land use planning and development. An explanatory background to this is presented in Box 1. In fact, recent research projects on this subject are being carried out. e.g. "BIM som informationsstöd för 3D fastighetsbildning" (Smart Built Environment, 2018).

3.1.2. SHARING SOLUTIONS IN THE REAL ESTATE SECTOR

The Forum for Sustainable Real Estate (Forum for hållbara fastigheter) was an initiative created in 2014 by Stockholm City’s Real Estate Office, with the objective of providing a space for sharing experiences on sustainability between real estate owners and managers (Fastighetskontoret, 2017). One of the main topics discussed in the forum was the role of buildings in the development of a circular economy and the challenges and possibilities of sharing solutions for products, space and services in the real estate sector (idem).

Two qualitative studies were published as a result of the work of the Forum for Sustainable Real Estate:
- The report “Nu gäller det att hänga med” (Now it is crucial to keep up) (Fastighetskontoret, n.d), provides an overview of different approaches, obstacles and driving forces for sharing solutions from the perspective of commercial property owners in Stockholm, capturing the current state of the discussion in the city.
- The report "KPI 2030: Nyckeltal för hållbara fastigheter" (KPI 2030: key figures for sustainable real estate) (Ekman et al., 2018), explores alternative indicators to describe the use and value of existing properties, as a complement to kWh/m2.

The following is an overview of key insights from both studies:

**Trends.** Thanks to digitalisation, the way we work has changed: we are connected, we don’t need paper and workplaces don’t need to be bound to one person (Fastighetskontoret, n.d., p.7). Meetings and social activities are the main reasons to go to the office, where social spaces create more value than individual ones (idem). Furthermore, tenants’ operations change quickly along with market dynamics and short-term planning requires accessible and flexible solutions (e.g. short-term or flexible rent contracts) (idem). At the same time, the role of the property owner is shifting from supplier of space to advisor, based on their specific competences and previous experiences (idem). There are different approaches to sharing, depending on the size of the businesses: small companies tend to share spaces and costs whereas big offices are willing to pay for more generous social spaces such as big lobbies, rooftops, cafeterias, etc. because they are interested in hosting clients or events (idem, p.12). However, the members of the forum point out that sharing most frequently takes place within the same organisation, which is relatively limited (idem, p.11). Although the environmental advantages are one important point in the discussion, real estate owners do not consider it to be the main driver for the development of sharing solutions (idem, p.5). They see better chances for a successful implementation in market-based solutions for different client
segments (e.g. commercial, residential), which would increase the attractiveness of the properties, thus adding social and economic value (idem, p.9).

**Demand.** The members of the forum are not sure about the actual market demand for sharing solutions, which in turn hinders the development of new initiatives as tenants do not have relevant options to ask for (idem, p.13). The members see sharing as a behavioral aspect that goes down to the individual level, determining what, where and how to share, often in conflict with "old" habits (e.g. ownership) that in turn determine the demand to a great extent (idem, p.6). Tenants play an important role here as well, because they are not always open to collaborate. The members suggest to test initiatives (e.g. pilot projects) outside of regulatory frameworks in order to find what solutions and business models could work and be able to offer alternatives to their customers (idem, p.20).

Some argue that old buildings are difficult to adapt as they might not be very flexible (idem, p.18). Rather, sharing solutions should be integrated in the early stages of the planning process of new constructions (idem), which some institutions in Stockholm have started to adopt as presented in Box 2. However, a focus on new construction might counteract many of the benefits of sharing solutions, such as the optimisation of use of existing buildings and the decrease of demand for space.

**Box 2. Stockholm City’s guidelines for school facilities**

The latest “Functions program for school facilities” (Funktionsprogram for skollokalen), (Utbildningsförvaltningen, 2018) provides a set of planning guidelines including flexibility and adaptability in renovations, extensions and new development of school facilities. The objective is to create well adapted rooms and activities both for current purposes as well as their long-term development according to the city’s vision of future education (idem, p.1, p.8). The guidelines describe how flexibility and adaptability should be planned in different rooms and activities in school facilities, including: entrance area, recreational areas, restaurant, kitchen, classrooms, sports facilities and outdoor areas (idem, p.2). According to the guidelines, flexibility is about highlighting the possibilities of activities to change and adapt to the environment with minimal means (idem). Thus, one guideline for entrance areas is e.g. plan the access to toilets according to eventual subdivisions of the school (idem, p.14).

Adaptability is about the possibilities of change over time if e.g. the number of students or the use of spaces would change (idem, p.2). One guideline for this is e.g. to arrange structural elements and shafts in a way that future spatial layouts won’t be limited (idem, p.28).

**Challenges and limitations.** The members acknowledge that sharing can lead to promising social, economic and environmental advantages but there is a lack of concrete examples and inspiration (Fastighetskontoret, n.d., p.14). The real estate is intrinsically rigid and static, whereas sharing solutions require flexibility and dynamic networks (idem, p.5). In the real estate industry, stability and security are highly valued, as opposed to flexibility and uncertainty (idem, p.17). Sharing solutions are seen as an unnecessary risk, especially when the market in Stockholm is performing well in terms of low vacancy rates (idem). The industry is conservative and wants to minimise risks, and sharing initiatives might counteract well established business models (idem). Current regulatory frameworks (e.g. hyresläget), technical constraints and reluctant actors represent major barriers. Who and how should operate sharing solutions is not clear, there is a need for new competences and ways of working “a gap to be filled in the value chain” (idem).
The regulatory framework is rigid and is not adapted to sharing solutions, since it is legally binding regarding who, how, when and what is to be rented. Moreover, it is only possible to rent out to a juridic person (e.g. company, association) (idem, p.19). Other kinds of tenure or conditions are only possible in a “second hand” type of contract (sublet), which makes it more difficult for an owner and tenant to use the property at different times of the day or consider different solutions (idem).

**Further development.** The report suggests different ways to further develop resource efficiency strategies in the real estate sector (idem). Thus, a) raising awareness on sharing solutions as a sustainability indicator/target for the management of buildings, b) creating partnerships and ways to collaborate between different stakeholders and c) testing initiatives outside of the regulatory framework are considered as main priorities (idem).

For example, big customers (tenants) can become influential by adopting initiatives and business models based on sharing solutions (idem). Alternative ownership options help to create new habits and behaviours (e.g. office-hotel) and attenuate the boundaries between managers (idem, p.20). Partnerships would allow a collaboration between different actors, making more resources available (e.g. area) (idem, p.21).

**Indicators.** Sharing is not included in the sustainability targets of the real estate industry, e.g. not included in certification labels (Fastighetskontoret, n.d.). Current parameters focus on floor areas and not the number of people who can use a space (Fastighetskontoret, 2017, Ekman et al., 2018). Some sources for example indicate that offices are typically used only 12% of the time, and even during that time (9h-17h) the degree of use is around 50% (Meerdc, n.d). New measurements and indicators need to be developed to give a broader picture of the situation.

The Real Estate Office and other partners initiated the study “KPI 2030: Nyckeltal för hållbara fastigheter” (Ekman et al., 2018) According to the study, it is crucial for tenants that the space is adapted for their activity and operations and to “feel proud when [they] come to the office” by creating an identity through both spatial layout and aesthetics (idem, p.19). Tenants prefer to have “their own” space, which represents a barrier when it comes to an efficient use of space or sharing solutions (idem). Thus, to let others use their space outside of the working/opening hours was not a popular idea and neither was sharing rooms or utilities/technical equipment (idem, p.33).

Figure 8. Temporal and spatial vacancies.

\[
Tv_{var dag} = \frac{\Sigma(ta)_{var dag} * \overline{B_g}}{24 \times 5} \\
Tv_{vecka} = \frac{\Sigma(ta)_{vecka} * \overline{B_g}}{24 \times 7} \\
Tv_{år} = \frac{\Sigma(ta)_{år} * \overline{B_g}}{24 \times 7 \times 365} \\
T_r = \text{Tidsvakans} \\
\Sigma(ta) = \text{Total användningstid} \\
\overline{B_g} = \text{Medelbrukargrad (dvs. hur stor andel av ytan som i snitt är använd)} \\
Yta_{vakans} = \frac{A_{BRA}}{A_{LOA} + A_{potentiell}} \\
Yta_{vakans} = \text{Ytvakans} \\
A_{BRA} = \text{Bruksarea} \\
A_{LOA} = \text{Lokalararea} \\
A_{potentiell} = \text{Potentiell area att bruka}
\]
The study joins the perspective of e.g. Höjer & Mjörnell (2018) regarding energy use measurements based only on kWh/m², as it leaves out important aspects of the actual use of the building in space and time (e.g. used area, number of users) (idem. p.4). As additional indicators, one of the project members suggests "time vacancies" (i.e. how many hours are spaces actually used/unused and how efficiently) and "area vacancies" (i.e. inactive areas that can have alternative purposes) (Ekman et al., p.21), which are presented in Figure 8.

The study concludes that by adding the “use dimension” in terms of time and activity, tenants and landlords could evaluate together how efficiently the spaces are used in time and identify ways to use the properties more efficiently, thus reducing the need for new construction (idem).

3.1.3. INSIGHTS FROM THE MARKET

In semi-structured interviews with sustainability managers of two big property owners in Sweden, we discussed their approach to the development of sharing solutions in terms monitored/available data, what partnerships they have or want to create, how their properties are used, experiences of sharing solutions and the future development of their businesses. Both companies are members of the Forum for Sustainable Real Estate and took part in the different seminars.

3.1.3.1 COMPANY A

Company A is one of the biggest property owners in Sweden. Its portfolio consists mostly of commercial properties rented out to businesses located in the main urban centres of the country. Environmental policy is highly prioritised and the company claims to be carbon-neutral.

Data. According to Manager A, Company A monitors various indicators of the resource use of its properties including the production and consumption of energy, emissions, indoor air quality, water consumption and waste. The different spaces they rent out are described in the contracts with the tenants, together with conditions regarding the use of the space e.g. business activities, location of space and area. Keeping track of these indicators constitutes a basis for the assessment and implementation of sustainability policies at the company, which account for its performance regarding sustainability targets, explains Manager A. Company A has implemented green financing through the issue of green bonds, and shareholders need to be informed about the compliance with sustainability targets.

Manager A sees great potential in the development of more ways to monitor the use of space with quantitative indicators. For Manager A, this can lead to the development of new services in line with the market dynamics and for a more efficient management of the properties. In some cases, there already exists the possibility to monitor how many people enter the building, as presented in Box 3.

Company A is currently working on the development of software in partnership with other property owners that would allow the implementation of sharing solutions, e.g. coordinate shared parking space with different properties or to apply machine learning features, explains Manager A. The collection of data of different processes and use of the buildings opens up new possibilities for their management.

“Company A” does not have a BIM model of all its properties, this kind of model is only limited to new constructions at the moment because the use of the format in the industry is more recent than many of their properties, which are only represented in 2D drawings. The budget for creating such a
model for older properties is not in the priorities, although “Manager A” recognises the necessity in the future.

**Use of properties.** Company A has been working on the development of new services for an increasing number of clients demanding flexible rent contracts, indicates Manager A. For example, they plan one “flexible” floor in a building with no fixed contracts, no fixed periods or even pop-up contracts. Thus, Company A offers a more flexible use of space that also enables a certain degree of sharing spaces, regulated by these contracts.

Company A is not involved in any 3D property configuration in Stockholm, to the best knowledge of Manager A. However, there have been discussions to use it for detaching some housing areas from commercial spaces. Another case where its application has been discussed is for the installation of solar panels on roofs, which in some cases is problematic because, as stated by Manager A, “as soon as you produce energy outside of your property boundaries, then it is taken up by the grid. It is not possible to export your excess energy to the grid and take it back”. This makes the investment less interesting.

**Experiences.** Manager A acknowledges the need to adapt to new demands in the retail and service sectors, which are evolving at a very fast pace. For instance, Company A started offering pop-up contracts with a weekly duration. Manager A explains that instead of renting a space to one single business, the property owner provides a fully equipped “ready to wear” space and rents it out to different businesses at different times of the day/week, where the rent would depend on popular times of the day/week.

Company A is still involved in large real estate investments and customised developments linked to clients that set out the spatial requirements, but they are actively working on the design of more flexible solutions. Since there is a growing demand for flexibility in the marker, they don’t need to use long-term contracts because they could create a tenant “rotation”, envisions Manager A.

Company A currently offers fully equipped office spaces “You sign your lease in the morning and you move in in the afternoon”, says Manager A. So far, only one tenant has used the possibility to resign

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**Box 3.** The tool Google's popular times visualises data on use of space in time through several indicators of the intensity of use of space. According to Google My Business (n.d.), the feature “Popular times” shows how busy a location is in the different days of the week, times of the day and in real time. The data for these indicators is collected, aggregated and anonymised from user’s enabled devices (idem). The average visit duration of the place and wait time estimates are also displayed (idem). The accuracy of these indicators is based on average popularity during previous weeks (idem).

*Image source: Google Maps*
the lease. The rest of clients using this kind of service are very satisfied, although they are probably paying an extra fee to have flexibility, according to Manager A.

**Partnerships.** Company A took part in the “Forum for Sustainable Real Estate”, where Manager A estimates that they were able make positive contributions and influence other participants by sharing their experiences and expertise in sharing solutions and the sustainable management of properties. Although the “FFSRE”, is not active anymore, Manager A stresses that “if we want to create a sustainable society, significant attention must be directed to the existing building stock. It is a gold mine in terms of environmental savings”.

Company A has alliances and partnerships with other property owners, e.g. for the development of facility management software (see Box 4). According to manager A, their partnerships with other stakeholders are established within different fields: in central areas, for example, they cooperate with municipalities and other real estate owners to improve urban environments and public space by e.g. financing maintenance or public events; attracting people to visit (shop) in less frequented areas of the city; improving public transportation by developing mixed-use projects. Sometimes partnerships evolve into formal structures such as environmental certification organisations. However, Company A is not currently involved in any partnerships for sharing solutions.

**Box 4. Real Estate Core**
In a consortium between leading real estate owners, an open source software tool is being developed as a solution for the management of the increasing data generated by smart technologies in buildings (Real Estate Core, n.d.). The sources of data include access systems, upcoming IoT elements and climate and lighting control among others. The aim of this platform is to create a “common denominator” that connects buildings to the “smart city” by merging management, operation and digital representations. It enables property owners to give their real estate portfolio access to services in a large scale, resulting in cost efficiency and environmentally friendly management of buildings (e.g. flexibility of use of space, energy consumption) (idem). Furthermore, it has the purpose of creating an environment for cooperation and sharing knowledge between property owners and partners.

**Business models.** Company A feels the pressure of other intermediation services such as WeWork\(^1\), a co-working company that, according to Manager A, does not own a single squared meter of space and yet it is one of the most profitable and valuable “landlords”, in the same way as Airbnb, one of the most profitable accommodation providers that does not own any hotel. Such intermediation services take advantage of tenant’s need for flexibility. Manager A points out that Company A is used to sign leases for 10-15 years and today not many tenants have that time perspective or don’t want to be bounded to geographic location. Based on these market trends, Company A thinks that big changes are coming up in digitalisation that will question or redefine the needs for space. According to Manager A, tenants are willing to pay more for flexible leases. For example, instead of signing a lease for five years, they want to have the possibility to end it within short notice periods e.g. 9 months. However, Manager A has realised that this flexibility is seldom used, but still companies will definitely opt for it and pay more.

Regarding office space, Manager A suggests that office work can be virtually done from any place with an internet connection and producing work is no longer the main reason to go to the office. According to Manager A, office space could become something more like a social space to spend

\(^{1}\) [www.wework.com](http://www.wework.com)
time with colleagues and clients and they are working to develop their properties from this perspective.

3.1.3.2 COMPANY B

Company B develops, owns and manages properties for community services such as nursing homes, schools and healthcare facilities. The company’s business model relies on long-term leases and stable tenants.

Manager B joined the company through a previous collaboration regarding a study on temporal and spatial vacancies within the company’s properties, i.e. availability in space and time. Manager B defines time vacancies as time slots where the tenants do not use their premises, e.g. a school that is not using its buildings/facilities during night, weekend, holidays. Space vacancies are, according to Manager B, physical spaces such as, roofs, walls, green areas, blue areas, hard areas belonging to the property. "You could develop those spaces, you can create value on them, add new functions e.g. solar panels on the roofs, walls can be used for displaying art, vertical gardens". Manager B sees “space vacancies” mostly in the exterior, or some interior elements such as walls.

Data. Company B does not currently have specific data or documentation of each property that would allow them to study temporal and spatial vacancies, but “as the landlord you always establish a contract with the tenant” and Manager B considers the conditions and information in the contracts a basis for it. However, "what the tenant does with its facility —within the conditions of the contract— is their choice", disclaims Manager B. The landlord has limited access to how the space is actually used by the tenants, "but technologies such as IoT would be interesting for that, with sensors and so on", suggests Manager B. Thanks to the efforts and interest of Manager B in this field, Company B has recently allocated a budget to start looking at how to measure and monitor time and space vacancies in their properties.

Company B does not have 3D models of their properties, except for some new buildings. The information they use is mostly 2D drawings. BIM is not used for facility management, they do not use any complex database. Manager B acknowledges that when it comes to property management there is a gap in the methods and information for monitoring resource and energy consumption, because the budget and other priorities do not always allow it. “For our property management, it would be nice to have one programme where all the information is compiled with the ability to filter specific aspects”.

Company B monitors mostly energy consumption and other indicators such as waste, as well as health and safety aspects within legal liabilities and environmental regulations. Sometimes this is outsourced to specialised facility managers and auditors, and new targets are set according to the assessment of the reports. From the tenant’s side, they do have a system to report inconveniences or damages.

Use of properties. Most of Company B’s properties are located in suburban areas and most of them are detached/single buildings typologies. According to Manager B, from a sharing perspective “it is challenging to bring enough actors together when the location is not dense, whereas for example in a city centre you can have easy access and good public transport to bring together different kinds of activities and actors”. It is difficult to increase the activities and uses in suburban areas as the demand is not very clear. Furthermore, the location of many properties makes them relatively isolated. “You need the demography in place to create a lively space”, stresses Manager B. In some
cases, there is no other reason to visit those buildings than for their own purpose, e.g. nursing homes or schools.

In a typical contract, the rent and conditions of use are established. For instance, Company B does not allow sublets. "According to the rent law we can't prohibit it for certain purposes. If a school wants to sublet out the gym to some association we can't say no, but if the school wants to sublet the whole facility, this might represent a conflict with the original purpose of the use", explains Manager B.

**Experiences.** Company B is currently working on sharing solutions to optimise the use of parking lots in their properties by creating a pool of clients/residents. When asked what "pilot project" they would like to develop if they had the possibility, Manager B said that in the past two years they have been trying to figure out how to scale up the use of time and space vacancies. Manager B has tried to plan for it, but only in a very small scale "perhaps a roof that has some solar panels, or one school that sometimes rents out a part of its facilities". But more volume can be gained by looking into what kind of buildings would be suitable and what kind of actors would be interested in optimising/sharing time vacancies. Manager B has been contacting different kinds of associations (sports, hobbies, cultural, etc) in order to find and create the demand for vacant spaces. "Associations gather sporadically and need affordable spaces. In many cases, they can adapt their activity accordingly so there is a good opportunity to develop the market for them. Studies have shown that they have a hard time finding suitable, available and affordable premises". Manager B points out that in Sweden there are around 244.000 associations (e.g. political, sports, hobbies) and that 80% of all Swedes are members of an association. How company B can facilitate a resource efficient use of their facilities at nights, weekends, as well as how easy it is to get other actors to use their facilities in controlled ways are questions that Manager B would like to explore.

The main obstacles/barriers for sharing spaces that Company B sees are the actual demand (it needs to be created) and regulatory frameworks that hinder the development of alternatives and do not provide enough guarantees.

**Partnerships.** Company B participates in partnerships with other landlords. For example, Company B has a joint venture with landlord who owns land in attractive locations, where Company B brings in its experience in management and development of public use facilities.

Since their biggest tenant is the public sector, municipalities are their main partners. Company B also participates in different kinds of initiatives (e.g. Forum for Sustainable Real Estate) and national research programs, and is currently involved in one project regarding the assessment of qualities of outdoor environments "we visit the buildings and it is also a way to create common knowledge about our properties" highlights Manager B.

**Business models.** According to Manager B, their properties do not challenge business models nor tenant's activities, focusing rather on delivering what the client asks for. "It would be very interesting if it did, but it's not the case in our business model". Company B usually builds the property according to the tenant’s requirements and how they want the space to be, "we are not that active in trying to think outside of the box" regrets Manager B, who sees the relevance of being involved in those kind of decisions, but it would require other competences and expertise in the company.

Company B usually works with very long contracts, with an average of 7 to 9 years, after which they are usually renewed. "The problem with very static contracts, is that it just goes on and you do not have room to do that much about the property, maybe small renovations. Only when the contract finishes there is an opportunity to consider bigger changes", says Manager B.
3.2 Describing the use of space in Hantverkargatan

The analysis and comparison of the collected data was guided by specific questions: *Who provides the space?* (management and supply); *Who uses the space? For how long?* (demand); *How much space? For what purpose?* (activities and economic aspects); *What kind of space?* (technical aspects).

3.2.1. OVERVIEW OF THE SAMPLE

The surveyed sample consists of 36 properties belonging to 32 different owners. 111 commercial spaces are included in the analysis, all of them are located at street level with direct access from the street.

**Buildings.** Most of the buildings are more than 100 years old and have been fully renovated at least once (according to official documents e.g. published annual reports of housing associations). In fact, 25 out of 36 properties were built between 1882 and 1912 —before World War I—. Nine additional properties were built between 1928 and 1939 (interwar period), and only two (1954 and 2018) have been added after World War II. The building typologies are rather homogeneous.

The majority of the properties (20) are classified in the “green” heritage category, meaning that they are considered particularly valuable from a cultural and historical point of view. The second largest group consists of properties in the “yellow” category (12), which highlights the cultural value of some of their architectural features. One property is in the “blue” category which is the highest level and 3 of them are not subject to any heritage protection class.

The ground floor of each property is subdivided into commercial spaces of different sizes and geometries. The average floor area of the spaces is 88 m². The smallest space has an area of 15 m² and the largest 427 m². The geometric reconstruction and dimensions of the surveyed spaces is represented in Figure 10.
Property owners. The ownership of the properties determines the type of tenure and management. Four types of property owners were identified: BRF (20 properties), associations (3), private persons (4) and companies (9). In the case of BRF, the type of housing tenure is *bostadsrätt*, which means that the residents jointly own and manage the property and only the commercial space is rented out. For the rest, the tenure is *hyresrätt*, i.e. one owner manages and rents out the apartments and commercial space.

*Bostadsrätt* owners (BRF) constitute housing association specific to the property that they use, whereas owners of *hyresrätt* can own more than one property, meaning that they are part of a larger network of shareholders not directly related to the use of the property.

In the case of *bostadsrätt*, the members of the housing association choose to whom they want to rent the commercial space. In the case of *hyresrätt*, this decision is made by the property owner.

Some owners own more than one property, which represents a greater capacity to supply space. This is the same case with some of the tenants that have several locations of their activities, representing a big demand.

Tenants. The commercial spaces were grouped into five categories: *goods* (35 units), *food* (33 units), *services* (21 units), *offices* (15 units) and *empty* (7 units), accounting for a total floor area of 9775.5 m2. Most of this area is used by goods (33.9%) and food (30%), followed by offices (19.7%) and services (11.3%). Empty spaces represent 5% of the total analysed area. Although a higher number of commercial spaces are used in “services”, offices appear to consume more space with fewer units.

<table>
<thead>
<tr>
<th></th>
<th>Area (m²)</th>
<th>Number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods</td>
<td>3316.0</td>
<td>35</td>
<td>33.9</td>
<td>31.5</td>
</tr>
<tr>
<td>Food</td>
<td>2930.0</td>
<td>33</td>
<td>30.0</td>
<td>29.7</td>
</tr>
<tr>
<td>Services</td>
<td>1108.5</td>
<td>21</td>
<td>11.3</td>
<td>18.9</td>
</tr>
<tr>
<td>Offices</td>
<td>1929.0</td>
<td>15</td>
<td>19.7</td>
<td>13.5</td>
</tr>
<tr>
<td>Empty</td>
<td>492.0</td>
<td>7</td>
<td>5.0</td>
<td>6.3</td>
</tr>
<tr>
<td>Total</td>
<td>9775.5</td>
<td>111</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

BRF primarily rent out their commercial space to businesses related to “food” (e.g. café, restaurant), followed by “goods”, whereas the other types of owner primarily rent out to businesses related to “goods” followed by “food” and “services”.

Figure 10. Surveyed commercial spaces (in colour). Blue = “goods”, green = “food”, yellow = “offices”, red = “services”. Source: Field survey and own drawings.
Table 4.2. Breakdown by type of owner and activity.

<table>
<thead>
<tr>
<th></th>
<th>Goods</th>
<th>Food</th>
<th>Services</th>
<th>Office</th>
<th>Empty</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRF</td>
<td>13</td>
<td>18</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>53</td>
</tr>
<tr>
<td>Private person</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Association</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Company</td>
<td>13</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>33</td>
<td>21</td>
<td>15</td>
<td>7</td>
<td>111</td>
</tr>
</tbody>
</table>

**Use in time.** Out of the 104 surveyed spaces, 85 of them regulate their operation with opening hours. 20 of them are open *by appointment* and 9 are not open to the public (invitation only). These categories do not exclude each other, i.e. some businesses combine both opening hours and appointments for less popular days of the week or times of the day. All the food-related and most of the goods-related activities use opening hours. Spaces that open upon request (by appointment) are popular among e.g. hairdressers. Other activities (e.g. offices) are not open to the public and the spaces are used by staff according to working time. In Sweden, the maximum number of working hours per week is 40 (Eurofound, 2017, p.10).

The opening hours of the shops were visualised in a matrix of 168 positions, representing the days of the week on the y-axis (7) and the number of hours in a day on the x-axis (24). As illustrated in Figure 11, the coloured cells represent hours where the space is used (open), the blank cells represent unused time slots.

According to the surveyed opening hours of commercial spaces in Hantverkargatan, the estimated use in time is around 30% of the week, meaning that 70% of the time the spaces are vacant.

![Figure 11. Visual overview of surveyed opening hours by activity.](image)

Source: Spreadsheet (see appendix).
3.2.2 (DE) COMPOSITION OF THE SAMPLE

This section describes and analyses the patterns of use of space found in the sample, based on activity groups (goods, foods, offices, services). The aim is to quantify and dimension the occupied space and time in order to see how the capacity of the existing spaces could be improved. Also, to a certain extent, it allows to have an idea of operational aspects of businesses and trends in the market. Differences in flexibility of hours of operation, the amount of space used, amount of hours needed and some technical aspects are presented.

Table 5.1. Average values in “Goods”, “Food”, “Office” and “Services”.

<table>
<thead>
<tr>
<th></th>
<th>Occupancy (%)</th>
<th>Hours per week</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Goods” average</td>
<td>30.1</td>
<td>50.5</td>
<td>94.2</td>
</tr>
<tr>
<td>“Food” average</td>
<td>35.7</td>
<td>60.0</td>
<td>88.8</td>
</tr>
<tr>
<td>“Office” average</td>
<td>23.2</td>
<td>39.0</td>
<td>126.8</td>
</tr>
<tr>
<td>“Services” average</td>
<td>32.0</td>
<td>53.6</td>
<td>55.0</td>
</tr>
</tbody>
</table>

GOODS

Goods is the largest group and accounts for 3316 m² of commercial space distributed in 35 shops. In terms of area, the main activities within this category are fashion (1100 m²) and grocery stores (865 m²), followed by stationery items (474 m²), health (403 m²), antiques (118 m²). Other shops with different purposes amount (346 m²). The size of the spaces ranges from 25 m² to 265 m², for an average of 94.2 m² per store. The space is mostly used to display or store merchandise. In some cases selling goods is combined with small workshops or services (e.g. jewellery, shoe repair, massages). Other stores are retail points of businesses whose production sites are done in a different location (e.g. furniture, food).

Table 5.2. Breakdown by type of goods, floor area and number of units in “Goods”

<table>
<thead>
<tr>
<th></th>
<th>Area (m²)</th>
<th>Number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fashion</td>
<td>1110</td>
<td>13</td>
<td>33.5</td>
<td>37.1</td>
</tr>
<tr>
<td>Grocery store</td>
<td>865</td>
<td>9</td>
<td>26.1</td>
<td>25.7</td>
</tr>
<tr>
<td>Stationery items</td>
<td>474</td>
<td>3</td>
<td>14.3</td>
<td>8.6</td>
</tr>
<tr>
<td>Health</td>
<td>403</td>
<td>2</td>
<td>12.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Others</td>
<td>346</td>
<td>5</td>
<td>10.4</td>
<td>14.3</td>
</tr>
<tr>
<td>Antiques</td>
<td>118</td>
<td>3</td>
<td>3.6</td>
<td>8.6</td>
</tr>
<tr>
<td>Total</td>
<td>3316</td>
<td>35</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The group of businesses established before 2000 is the largest (60%) and mainly consists of fashion and grocery stores, followed by some independent workshop activities. Most of these businesses have several other locations across the city, in the country and/or abroad. The group 2000-2010 (20%) consists almost entirely of independent fashion stores (single locations) and the group after 2010 (20%) uses the space for selling fashion articles and groceries, with half of the businesses present in other locations.
**Use in time.** Based on opening hours, “goods” accounts for a total of 1567 hours per week, most of them spent from Monday to Friday between 10h00-18h00, making it quite homogeneous with the exception of some grocery stores that usually extend their activity into late nights. The activity in “Goods” is almost entirely regulated by opening hours (except 4 shops, that are appointment only) and sometimes complemented by appointment options for those with reduced availability.

<table>
<thead>
<tr>
<th>Hours per week</th>
<th>average occupancy %</th>
<th>area (m2)</th>
<th>number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 20</td>
<td>7.1</td>
<td>69</td>
<td>2</td>
<td>2.4</td>
<td>6.5</td>
</tr>
<tr>
<td>21 - 40</td>
<td>20.0</td>
<td>388</td>
<td>9</td>
<td>13.3</td>
<td>29.0</td>
</tr>
<tr>
<td>41 - 60</td>
<td>28.2</td>
<td>1447</td>
<td>13</td>
<td>49.6</td>
<td>41.9</td>
</tr>
<tr>
<td>61 - 80</td>
<td>41.4</td>
<td>599</td>
<td>4</td>
<td>20.5</td>
<td>12.9</td>
</tr>
<tr>
<td>81 - 100</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>101 +</td>
<td>115.7</td>
<td>416</td>
<td>3</td>
<td>14.3</td>
<td>9.7</td>
</tr>
</tbody>
</table>

The number of hours each space is used per week varies from 4 to 117, making up for an average of 50.5 hours/week. The lowest belongs to a lingerie shop with a strong presence online, whereas the highest is performed by a grocery store that opens every day from 7h00/8h00 to midnight. In most of the independent businesses, this rate is kept below 40h/week which corresponds to a work week. The occupancy rate follows the same pattern as the number of hours per week, with an average rate of around 30%, ranging from ca. 2% to 70%.

**FOOD**

Food is the second largest group and accounts for 2930 m2 of commercial space distributed in 25 restaurants, 6 cafés and 2 bars. In terms of area, restaurants occupy 2239 m2 (76%), cafés 527 m2 (18%) and bars 164 m2 (6%). The size of the spaces ranges from 15 m2 to 294 m2, for an average of 88 m2 per business. The space is used by staff and visitors for two main functions: kitchen and seating area, making up for 33 kitchens and a considerable amount of furniture (not surveyed).

<table>
<thead>
<tr>
<th>Restaurant</th>
<th>Area (m2)</th>
<th>Number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2239</td>
<td>25</td>
<td>76.4</td>
<td>75.8</td>
</tr>
<tr>
<td>Café</td>
<td>527</td>
<td>6</td>
<td>18.0</td>
<td>18.2</td>
</tr>
<tr>
<td>Bar</td>
<td>164</td>
<td>2</td>
<td>5.6</td>
<td>6.1</td>
</tr>
<tr>
<td>Total</td>
<td>2930</td>
<td>33</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The group of businesses established after 2010 is the largest (58%) and contains almost all the cafés and bars, except for 2. Most of these businesses are independent and have only one location in the city, with a small amount with more than 2 locations, whereas in the group “2000-2010” (21%) and “before 2010” (21%) more than half of the restaurants have between 2-4 locations.
Use in time. Based on opening hours, “Food” accounts for a total of 1980 hours per week, most of them spent from Tuesday to Friday between 11h00-21h00. The activity in “Food” is entirely regulated by opening hours which focus on meal times (breakfast, lunch, dinner, fika) until late night service. Thus, 3 addresses (136 m²) only open during lunch (ca. 11h-14h) and 4 restaurants (481 m²) only from ca. 17h00 in the afternoon.

<table>
<thead>
<tr>
<th>Hours per week</th>
<th>average occupancy %</th>
<th>area (m²)</th>
<th>number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 20</td>
<td>10.4</td>
<td>91</td>
<td>2</td>
<td>3.1</td>
<td>6.1</td>
</tr>
<tr>
<td>21 - 40</td>
<td>18.3</td>
<td>511</td>
<td>5</td>
<td>17.4</td>
<td>15.2</td>
</tr>
<tr>
<td>41 - 60</td>
<td>32.1</td>
<td>386</td>
<td>7</td>
<td>13.2</td>
<td>21.2</td>
</tr>
<tr>
<td>61 - 80</td>
<td>43.3</td>
<td>1862</td>
<td>18</td>
<td>63.5</td>
<td>54.5</td>
</tr>
<tr>
<td>81 - 100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>101 +</td>
<td>61.3</td>
<td>80</td>
<td>1</td>
<td>2.7</td>
<td>3.0</td>
</tr>
</tbody>
</table>

The number of hours each space is used per week varies from 15 to 103, making up for an average of 60 hours/week. The lowest belongs to a small shop serving only lunch, whereas the highest is performed by a sports bar that opens every day from 10h00/10h000 to 01h00. Most of the businesses (25) are open between 40-80h/week, i.e more than a work week. The occupancy rate has an average rate of 35%, ranging from ca. 8 to 61%.

OFFICES

“Offices” account for 1929 m² of commercial space distributed in 15 units. The size of the spaces ranges from 26 m² to 427 m², for an average of 128.6 m² per space. The most common tenants within this category are businesses such as law firms and real estate agents (9 units), followed by artistic productions (4 units) (e.g. graphic design, audiovisual productions) and other social/educational activities (2 units).

<table>
<thead>
<tr>
<th>Business</th>
<th>Area (m²)</th>
<th>Number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>1529</td>
<td>9</td>
<td>79.3</td>
<td>60.0</td>
</tr>
<tr>
<td>Artistic productions</td>
<td>189</td>
<td>4</td>
<td>9.8</td>
<td>26.7</td>
</tr>
<tr>
<td>Social / education</td>
<td>211</td>
<td>2</td>
<td>10.9</td>
<td>13.3</td>
</tr>
<tr>
<td>Total</td>
<td>1929</td>
<td>15</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
The different activities are homogeneously distributed in terms of age of the businesses and most of them have several locations in other parts of the city or abroad. However, businesses in the category “After 2010” have fewer or unique locations.

Table 7.2. Age of business and number of units in “Offices”

| Before 2000 | 4 |
| 2000-2010   | 6 |
| After 2010  | 5 |

Use in time. Only 5 out of 15 businesses in “offices” have official opening hours and are open to the public, distributed homogeneously from Monday to Friday between 9h00 to 17h00, for an average of 37.6 h/week, which corresponds to a work week. The 10 other businesses with no data are assumed to follow the same pattern, thus making the maximum hours per week not higher than 45. One business has shifted the work week from Tuesday to Saturday.

SERVICES

“Services” accounts for 1108.5 m² of commercial space distributed in 15 beauty salons, 2 laundries, 1 gym and a group of 3 other businesses. In terms of area, beauty salons are the main tenants with 639.5 m² (57.7%), followed by the group of “other businesses” with 240 m² (14.3%), the gym with 170 m² (15.3%) and the laundries with 59 m² (5.3 %). The size of the spaces ranges from 17 m² to 170 m², for an average of 52.7 m² per business. The space is used as small workshop where special equipment and tools characterise the activity (e.g. hairdressers, gym).

Table 8.1. Breakdown by type of service, floor area and number of units in “Services”

<table>
<thead>
<tr>
<th>Area (m²)</th>
<th>Number of units</th>
<th>% of total area</th>
<th>% of total units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beauty</td>
<td>639.5</td>
<td>15</td>
<td>57.7</td>
</tr>
<tr>
<td>Gym</td>
<td>170</td>
<td>1</td>
<td>15.3</td>
</tr>
<tr>
<td>Laundry</td>
<td>59</td>
<td>2</td>
<td>5.3</td>
</tr>
<tr>
<td>Other</td>
<td>240</td>
<td>3</td>
<td>21.7</td>
</tr>
<tr>
<td>Total</td>
<td>1108.5</td>
<td>21</td>
<td>100</td>
</tr>
</tbody>
</table>

The group of businesses established after 2010 is the largest (52%). Beauty salons are evenly distributed over all the periods. All the businesses in “services” rent a single location in the city.

Table 8.2. Age of business and number of units in “Services”

| Before 2000 | 3 |
| 2000-2010   | 7 |
| After 2010  | 11|

Use in time. Based on the surveyed opening hours, “services” accounts for a total of 805 hours per week, most of them spent from Monday to Friday between 10h00-18h00. However, the activity in “services” is not entirely regulated by opening hours (15 out of 21 shops). Appointment options are
widely available among beauty salons, which is the most representative activity of this category. This is interpreted as flexibility in use of time.

Table 8.3. Breakdown by opening hours per week in “Services”.

<table>
<thead>
<tr>
<th>Hours per week</th>
<th>average occupancy %</th>
<th>area</th>
<th>% area</th>
<th>number of units</th>
<th>% units</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>21 - 40</td>
<td>19.8</td>
<td>86</td>
<td>10.4</td>
<td>3</td>
<td>20.0</td>
</tr>
<tr>
<td>41 - 60</td>
<td>28.5</td>
<td>465.5</td>
<td>56.4</td>
<td>10</td>
<td>66.7</td>
</tr>
<tr>
<td>61 - 80</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>81 - 100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>101 +</td>
<td>67.6</td>
<td>274</td>
<td>33.2</td>
<td>2</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Most of the spaces are used between 30 and 55 hours per week (beauty salons), with 2 exceptions (106h for the gym and 121h for another facility), making up for an average of 53.6 hours/week. The estimated occupancy rate has an average of 32%, ranging from ca. 18 to 72%.
In the previous section, main factors that influence the capacity to accommodate activities in space and time in existing buildings were presented: spatial layouts determine the available floor area, business models define operational hours and management has an influence on the type of activities.

The survey of opening hours shows that there are a few complementary opening hours, i.e. businesses that only open e.g. between 10h - 16h, and other only from 17h - 24h. According to the tables below, businesses from Table 9.1 could be absorbed by the ones in Table 9.2, thus freeing up 404 m² that could be used for new businesses or other purposes. However, the subdivision of the spaces given by property boundaries and building typologies are a limitation for this kind of operation. Also, the compatibility between the activities is not always obvious for operational reasons. For example, a restaurant might not be compatible with a clothing store or an office for hygiene reasons.

<table>
<thead>
<tr>
<th>Table 9.1. Matching hours (morning)</th>
<th>Table 9.2. Matching hours (evening)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10h - 16h</td>
<td>17h - 24h</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Restaurant</td>
</tr>
<tr>
<td>45 m²</td>
<td>180 m²</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Restaurant</td>
</tr>
<tr>
<td>60 m²</td>
<td>30 m²</td>
</tr>
<tr>
<td>Café</td>
<td>Restaurant</td>
</tr>
<tr>
<td>15 m²</td>
<td>51 m²</td>
</tr>
<tr>
<td>Café</td>
<td>Restaurant</td>
</tr>
<tr>
<td>40 m²</td>
<td>220 m²</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Clothing store</td>
</tr>
<tr>
<td>31 m²</td>
<td>25 m²</td>
</tr>
<tr>
<td>Office</td>
<td></td>
</tr>
<tr>
<td>Antiques</td>
<td></td>
</tr>
<tr>
<td>44 m²</td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td></td>
</tr>
<tr>
<td>35 m²</td>
<td></td>
</tr>
</tbody>
</table>

In the suggested example above, a big restaurant open in the evening could absorb four smaller restaurants and cafés open during the morning. The big restaurant has enough area and the opening hours do not overlap and they could even share the kitchen. This is possible because all of them have a rather low use of space in time, but when it is aggregated, the efficiency of use increases.

**SHARING SPACES**

In an attempt to generalise the previous example, an increase of use of space through sharing solutions could be achieved. Two different sharing options are outlined by combining:

a) Dimension of the space (m²)

b) Number of hours that the space is used per week (e.g. opening hours).

c) The rate of occupancy (use) as a proportion (%) of 168 h = 1 week.

d) The maximum capacity of the space, i.e. maximum hours that the area can be used expressed in (m² x 168h).
Figure 12 illustrates the situation described in the example. Space A is currently used 19% of the time of the week. Its area and operational hours would allow Spaces B, C, D and E, whose spatial and temporal capacity would match with A.

In Figure 13, a new Space Z represents the added activity from A, B, C, D and E. The occupancy of space Z thus increases to 34% of the time and the area originally occupied by B, C, D and E is now free.

Figure 14 illustrates an intermediary option, where B, C, D and E partially share the space with A, increasing the efficiency in A to 25% (compared to the original 19%) and reducing the need for space in the others. Detailed calculations are included in the appendix section.
According to the previous demonstration, a “full sharing” situation is illustrated in Figure 13. In this case, different activities manage to share one single space in different time shifts (e.g. morning, afternoon, evening). A simultaneous use of the shared space might be operationally constraining, unless the activities are specifically adapted for this purpose. It is the most efficient option, as it fully adds up the occupancy rate of different activities and frees up a greater amount of floor area.

“Partial sharing” is illustrated in Figure 14. This situation would allow different activities to share one part of their space (e.g. seating area) while keeping exclusive rights of use on other parts. Thus, the shared space does not need to be alternated in different time shifts. It can be used simultaneously, as it does not cause major operational constraints, but rather synergies. "Partial sharing" is more efficient as a separate use, but not as much as “full sharing” in terms of spared floor area. However, it offers an alternative for activities that require exclusive spaces for operational reasons.

Within the different categories, sharing possibilities and trends can be identified, according to the insights from the interviews in sections 3.1.3 and 3.3.2. In “food”, equipments such as kitchens, seating areas and furniture can be shared (Andersson et al., 2018). Foodcourts somehow operate under this principle. In “goods” space for stocking merchandise can decrease thanks to digitalisation (online shopping) (Reynolds & Sundström, 2014). Current trends focus on showrooms that can be used for different purposes in order to enhance the customer experience. Some examples of this trend are the Arket Café2 (clothing store and café) and Nike trial zones3 (sports gear and training area).

In “services”, spaces could be shared between services that use similar equipment and similar space configuration but with different operational hours (e.g. dentist, hairdresser, laundry). In “offices”, with increasingly flexible working hours, office spaces and furniture could be shared between different firms (Andersson et al., 2018). As a result, gains in floor area could be filled with community functions (e.g. library, meeting points, public space)

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3 Nike Trial Zone. https://www.niketrialzonecasestudy.com
3.3 New property formations

The generalisation of the example in section 3.2.3 suggests that matching existing opening hours within existing spatial configurations alone does not necessarily challenge business models (both for demand and supply) and probably does not create a significant volume. Despite the ability to implement such initiatives within existing property boundaries, operational, technical and spatial constraints of different businesses might significantly reduce the number of feasible "pairing" options.

Further optimization of use of existing spaces could be achieved through changes in business models and property boundaries need to be introduced in order to have a bigger impact in terms of resource efficiency and reduction of need for new construction (confirmed by interview consultant Z, see 3.3.2). If property boundaries defining management and spatial subdivision would be reconfigured, the capacity in terms of available floor area for sharing space would increase, as discussed in section 3.2.3. Moreover, digitalisation tools would help businesses and management to gain efficiency of distribution in time. This section explores how the formation of 3D properties could be a way for achieving this.

3.3.1 IMPLEMENTATION OF 3D PROPERTIES IN STOCKHOLM

In a short conversation with a Senior real estate analyst who has experience working with 3D property formations in Stockholm, the implementation of 3D properties in Stockholm was discussed. Analyst Z worked as a consultant during the inquiries preceding the law in 2004 (Sveriges riksdag, 2003).

According to Analyst Z, the implementation of 3D properties in Sweden was the outcome of mixed use developments happening in the bigger cities, "the pressure [to implement 3D properties] came naturally from big cities in Sweden". Thus, 3D properties were conceived as a tool for the management and development of different functions within one property. From a market perspective, it would allow specialised companies and real estate professionals to better represent different areas of interest (e.g. housing, retail, offices, hotels). Analyst Z points out that before the introduction of 3D properties in Sweden, the possibilities for mixed used configurations were limited. One landlord had to be capable and willing to take care of all the functions/uses within a property. The mix of uses and activities relied on contracts that were not very flexible and limited the involvement of different actors.

Although introduced more than 10 years ago, only in the last 5 to 7 years Analyst Z has noticed a big change in the demand for this kind of property formation. "If you had asked me 7 years ago, 3D properties were not in the agenda of real estate actors". Analyst Z argues that it happened very little in the first five years after the introduction of the law, but now more developers have taken an interest in this and want to test it.

According to Analyst Z, the mix of functions in the city is crucial for contemporary urban economies and mixed use is the "planning concept for contemporary challenges". From a market perspective, Analyst Z notes that there is high interest and demand from private and public sectors. For example, it is increasingly noticeable in the Stockholm region the case of BRF that want to sell out the commercial spaces at the street level because of tax reasons. If the commercial part of the property represents more than 40% of its commercial value, the taxation is much higher for the BRF and its
members. Furthermore, this instrument could be useful to assist current transformations of the real estate market by optimising traditional processes of demand and supply of spaces. In Stockholm, for example, “online shopping has significantly challenged the retail sector and we have noticed the conversion of many retail space into restaurants, along with an increasing demand for hotels”, indicates Analyst Z.

3.3.2. DEVELOPMENT OF SHARING SOLUTIONS

Consultant Z currently works in the field of sustainable consumption, where sharing solutions has been an area of interest. Focusing on social aspects and the environmental benefits of sharing, an interview was conducted in order to have the perspective of an expert outside of the real estate field and to learn more about Consultant Z’s approach to the development of sharing solutions. A semi-structured interview was used to guide the discussion, based on the reports of the organisation where Consultant Z works (Andersson et al., 2018) and the proposal of this study.

Sharing economy. Consultant Z points out that there are potential benefits of sharing in terms of reduction of energy consumption and GHG emissions. Specifically, Consultant Z sees embodied impacts as a key measurement to promote sharing solutions. For example, thanks to the very low-emission energy mix in Sweden, the furniture and interior design in buildings might be the biggest source of energy consumption and GHG emissions because of the embodied impact of the extraction of materials, production and transport from countries with other energy mixes.

According to Consultant Z, sharing space has greater savings potential than that of an optimised energy use in the operational phase of a building. In theory, sharing space reduces both energy consumption and embodied impacts of new construction e.g. lower need for material, furniture and equipments. However, this relationship is not that straightforward. Consultant Z stresses that this depends on how the sharing solutions are designed. For example, sharing the space means increasing its use in time (e.g. 24h) and therefore its operational energy use, but on the other hand, saving space also means saving furniture, equipment, lighting and other elements with a considerable embodied impact. At the same time, e.g. in activity based offices, various studies estimate the potential to save space. However, this kind of office layout includes social areas that sometimes are over-dimensioned, which counteracts the actual savings of space. “You want people to be flexible and be able to sit in different places and you create a lot of them… So at the end of the day it is not sure that we actually save space” highlights Consultant Z.

Business. Consultant Z warns of the rebound effects that often come with sharing solutions. Looking at new business models and new ways of consumption, sometimes savings obtained through new solutions (e.g. energy, money) actually increase consumption, as consumers often look for opportunity to spend what they saved (e.g.”it’s cheaper then I buy more”). For Consultant Z, as long as new business models follow the same patterns of ordinary market rules of consumption, the actual savings through sharing solutions effect will be marginal. Consuming services (e.g. each other’s time) might have a lower environmental impact, but when it comes to material consumption, it definitely needs to decrease.

Sharing has a very interesting potential to influence attitudes and behaviour, for instance the way we consume. It actually introduces structural change and it should be promoted from this perspective. For example, by prioritising access over ownership “I pay to have access to something at a certain time, I don’t own it anymore”. Sharing changes feelings and status associated to ownership and
creates the habit of using instead of consuming. Whether a transaction is involved or not, it doesn’t matter that much, because it is the same habit if I share something in my property or if I pay for a sharing service. Sharing space could definitely be a part of that change of habits. There are different motivations for having access to something rather than owning it, including: convenience, costs, limited (shared) liabilities, less stress, the feeling of belonging to a community, build trust.

To summarize, sharing solutions for spaces have the potential to create the additional savings of embodied energies in the interior design and equipment (e.g. furniture), which are significant in contexts where energy mixes have a low environmental impact. When speaking of sharing commercial spaces, sharing solutions should be the designed taking into account the risk of rebound effects that might counteract the intended savings.

3.3.3. RE-CONFIGURING PROPERTY BOUNDARIES

Figure 15 illustrates in schematic elevations, the different options for the reconfiguration of property boundaries according to the definitions provided in El-mekawy et al. (2014, p.20) and Paulsson (2012, p.198). Based on the urban structure of Hantverkargatan (closed urban blocks), the illustrations are used to discuss and to compare the possibilities and implications of different property subdivisions.

1. Traditional 2D properties

2. Single 3D properties

3. Merged 3D property spaces

4. New property + new business models

Figure 15. Options of new property formations in existing properties (code type 321).

1. Traditional 2D properties. A, B, C and D are traditional 2D property units, i.e. they are virtually delimited by a 2D geometric construction and each owner has exclusive rights on the properties and constructions attached to it (Julstad & Ericsson, 2001). The use of the property by third parties is regulated by agreements such as rental contracts (Paulsson, 2012, p.197). Assuming that these properties combine housing and commercial functions (code type 321) as in the case of...
Hantverkargatan, the management of the commercial part of the property is often problematic as mentioned in Smeder & Mardi (2017), Sveriges riksdag, (2003) and confirmed with the interviews with Analyst Z and Manager A. The current regulatory framework does not allow tenants in the commercial part to use it for other purposes when the business is closed, e.g. subletting, sharing is not enabled (Fastighetskontoret, n.d., Analyst Z, Manager B). The fragmentation of management and use of commercial spaces often results in an inefficient occupancy (figure 12, section 3.2.2). Opening hours established by businesses determine the accessibility and street life. In this configuration, there is little room for partnerships, and it does not create a common understanding of the use of space as a sustainability indicator (Consultant Z, Fastighetskontoret, n.d.).

2. Single 3D properties. Separate 3D property units are created to divide housing and commercial functions. As defined in Paulsson (2012, p.198), the new 3D property must relate to an existing construction and is delimited in height and depth. According to Smeder & Mardi (2017) and Analyst Z, early signs of the development of this trend in Stockholm are becoming more visible. This configuration represents a change in the management of the commercial spaces. If the new owners would have specialised competence in retail/commercial spaces, a better mix of functions and sustainability policies could be developed (Manager A). Moreover, the creation of more 3D property units would encourage the development and broader implementation of this instrument (Analyst Z). It would enable find ways to develop sharing solutions and pilot projects for sharing solutions outside of the current regulatory framework of traditional 2D properties (Fastighetskontoret, n.d.). If the dimensions of the new spaces would allow for it, "partial" or "full sharing" could be implemented (see section 3.2.3), thereby increasing the efficiency of use of spaces to a certain extent. Otherwise, it would be a very small unit to optimise and the impact on energy savings would be probably marginal (Manager A).

3. Merged 3D property spaces. The concept of “3D property space” explained in El-mekawy et al. (2014, p.20) refers to 3D property formations included in a different 2D property unit (see figure 7, section 3.1.1). In the case of the above illustrations, adjacent properties. Here, a larger portion of floor area is merged and can be managed in a more flexible way, which is one of the main obstacles for sharing spaces highlighted in FFSRE (section 3.1.2). This opens up entirely new possibilities for the use of space through e.g. flexible rental contracts and sharing solutions (Fastighetskontoret, n.d.). The mix of activities and the efficiency of the new space can be measured and planned (Manager A). This could lead to the implementation of resource-efficiency policies in those spaces and a mix of activities that enhance the quality of urban environments. More activities can be accommodated in space and in time, which generates potential savings in energy consumption and embodied impacts (see section 3.3.2, Höjer & Mjörnell, 2018). Moreover, the necessary new investments and renovations would contribute to motivate the implementation of energy efficiency measures for existing buildings (Thuvander et al., 2012, p.1192, European Commission, n.d.). Furthermore, this might create an opportunity to create BIM models of existing buildings that do not have it (Manager A, Manager B, El-mekawy et al., 2014), and the data could be use to develop long-term indicators for the management of the properties. However, this operation might entail the modification of existing detail plans and push the development of a 3D cadaster (El-mekawy et al. 2014), in order to accurately register and tax the resulting properties.

4. New property and new business models. This option follows the same structure as the previous one, but resource efficiency, achievement of environmental goals and the enhancement of qualities in urban environments are highly prioritised. For example, spared floor area can be used to develop community functions (non-commercial) and sharing solutions should be able to introduce changes in
behaviours and attitudes (Consultant Z). The design of spatial layouts, the management and business models engage tenants, owners and users in “sharing” beyond economic benefits, to pursue a cultural and political development (McLaren, 2016).

Note: "Manager A" and "Manager B" refers to the interviews in sections 3.1.3.1 and 3.1.3.2. "Analyst Z" and "Consultant Z" refers to the interviews in sections 3.3.1 and 3.3.2.

3.3.4. NEW PROPERTY FORMATIONS

Figure 16 represents how new 3D property formations could be used to merge commercial spaces at the street level, taking Hantverkargatan as an example. Here, ownership and management of housing and commercial spaces are decoupled, which establishes new opportunities for the development of sharing solutions. Figures 15 and 16 were used as a basis for a discussion with experts on the fields of sustainable real estate (manager A) and sustainable consumption (Consultant Z) in order to corroborate the interest, relevance and risks of the proposal.

Figure 16. Formation of an optimised 3D property (Z, Y…) in Hantverkargatan

1 - Existing Commercial spaces on the street level
2 - Traditional (2D) properties (A, B, C…)
3 - Formation of single 3D properties (A1, B1, C1…)
4 - Merged single 3D spaces (Z, Y…)
Manager A. Based on the illustrations (figures 15, 16), the concept for new property formations was presented to Manager A (interview in section 3.1.3.1), who found it innovative and interesting as a way to think the development of new services and business models. According to Manager A, the proposal would represent a new opportunity for property owners to develop their retail portfolio that has not been considered before. Based on previous experiences, Manager A highlights that the current management of that kind of retail space (street level commercial, housing on top) is done on an individual basis, which often causes a lack of attractiveness of the property. Moreover, a good mix of retail cannot be planned and underused or overcrowded spaces appear due to the lack of professional expertise.

Another important aspect of this for Manager A, is that even if there were sustainability policies regarding one shop, the impact would be marginal at the urban scale, as individual shops at the street level represent a very small space to optimise. But merging them into a single property opens up different opportunities. For example, Company A could offer different types of contracts based on time slots and develop the interior design accordingly, which Manager A thinks would become a more affordable solution for certain tenants.

However, Manager A sees number of technical issues that emerge with this kind of operations. Company A currently does not have 3D properties in their portfolio (at least in Stockholm) for a number of reasons including the obstacle of defining rights of use and liabilities of utilities such as electricity and water supply.

Consultant Z. Based on the illustrations (figures 15, 16), Consultant Z formulates different recommendations. For example, if the main function of the new 3D property at street level would be only commercial and owned by a private investor, there is a risk of losing diversity “who owns the city?”, questions Consultant Z. However, this depends on how the solution is designed. There are interesting possibilities of mixing public space and commercial space in new ways. “When you do that, it also changes the ideas about what you do or the way you use certain spaces”. Consultant Z suggests that the habit of going to the shopping mall during the weekend to buy something could be different if you would have a mix of different functions other than commercial, or other ways of consumption supported by spaces “where you are allowed to be, to share, to be creative". According to Consultant Z, it would be important to establish certain requirements for the implementation of the proposal. Regulations regarding the mix of uses as a complement to the commercial parts could be done by including a proportion of area dedicated to public facilities such as libraries, meeting points, etc. Besides the relevance for increasing property value and environmental savings, it is crucial to contribute to the creation of better urban environments, stresses Consultant Z.

One of the main conflicts that Consultant Z sees with the proposal is a potential commercialisation of the street level and public space at the expense of traditional common spaces in residential buildings such as courtyards, laundry rooms, “festlokaler”, etc. In order to simultaneously maintain and promote the sense of community —which is crucial for sharing—, it would be important to establish partnerships and to cooperate with the residents of the buildings, suggests Consultant Z. Consultant Z stresses the importance of developing incentives for sharing solutions. From a user perspective, this could be done through new activities and experiences that strengthen community values. It would give reasons to visit and use the new spaces other than for commercial purposes, contributing to make the new spaces more inclusive. For investors, sharing solutions should help to form agreements and partnerships to share risks and costs, and ownership could used as a tool for representing different groups of stakeholders.
4. Discussion and conclusion

This study suggests one way to optimise the use of space in existing buildings by creating new property rights. Specifically, it illustrates how merging commercial spaces on the street level through the constitution of 3D properties can increase the capacity to accommodate activities in space and time. Together with the development of new business models and services based on sharing solutions, this opens up new possibilities for a resource-efficient use of space.

The notion of building stocks introduced in Kohler & Hassler (2002) is highly relevant for this study, as it encourages to consider existing buildings as a resource that needs to be preserved and managed efficiently. In a similar way, some land use policies highlight the value of land as a limited resource in contexts where land is scarce and there is high pressure from demographic growth. One example of response to this is the policy to promote storey extensions instead of new construction on new land, implemented in Geneva, Switzerland (République et Canton de Genève, 2016).

Current urban developments in Stockholm are based on traditional 2D properties, where functions are attributed to undeveloped plots of land (e.g. land allocation procedures) (Caesar, 2016). A recurrent reflection during the inquiry was whether current urban planning processes typically lead to new construction and further consumption of new land, leaving out the opportunities of considering existing buildings to respond to new demands for floor area. Although this was out of the scope of the study, it would be important to verify in order to support the relevance of the proposal.

While similar patterns of ownership and use of space have been observed in other streets of central Stockholm (see section 2.2), the generalization of the proposal must be examined in a broader scale, i.e. different areas of the city. Nevertheless, this might entail the use of different methods other than the ones used for the present study (e.g. GIS, surveys), which can indeed be based on the results of this inquiry. Furthermore, it would be also necessary to study cases where 3D properties involving both housing and commercial spaces have already been implemented and evaluate their impact on the efficiency of use of space.

Examples of unified commercial spaces exist in form of galleries and food courts in Stockholm. The crucial difference with the proposal of this study is that they had originally been planned for that very purpose. The unique opportunity facilitated through the formation of 3D properties is the possibility to transform ways of using parts of existing buildings.

The field survey corroborated trends pointed out in interviews (Analyst Z) such as the lack of expertise in management of commercial spaces and the survey of opening hours shows that there is room for optimisation of commercial spaces in the way they are operated. However, how a mix of functions in a unified space could work and how business models would need to be adapted must be investigated.

Energy performance classifications (Boverket, 2018) and type and duration of rent contracts were not taken into account in this study as the data was not accessible for all the surveyed properties, which would not allow for a comparison. However, these indicators would have been crucial to get measurements for real use of space and energy consumption. A similar study based on energy performance certificates was carried out in Gothenburg (Osterbring et al, 2017).
Despite the mentioned shortcomings in the management of commercial spaces by BRF, this housing tenure form remains interesting as its members are the residents themselves, which guarantees to a certain extent their involvement in the decision of who occupies the commercial space at the street level in their property. Future partnerships with a unified commercial space (as illustrated in section 3.3.4) could be created following this principle.

The potential main benefits of a broader implementation of the proposal would be:
- the contribution to the fulfillment of environmental goals in the upcoming decades.
- the development of sharing solutions from a resource-efficiency perspective.
- to provide alternatives to preserve and add value to the existing building stock.

Environmental goals. A more efficient use of existing space would contribute to the reduction of energy consumption and GHG emissions in different ways, as discussed in Höjer & Mjornell (2018). According to this study, an increased capacity to accommodate activities in time would intensify the use of spaces with low occupancy. When different activities are able to share a space, the total floor area they occupy is reduced if compared to that of a separate use. Thus, additional floor area becomes available without new construction: some spaces are saved through sharing while other spaces are freed up. The new available area can then absorb new demand for space or be used for different purposes.

In principle, this study assumes that reducing the amount of occupied floor area reduces energy consumption from HVAC systems (heating, cooling, ventilation). In that sense, it is suggested that making additional floor area available without new construction would represent savings in energy use and embodied impact of future (unbuilt) buildings. If successfully implemented, this twofold strategy would contribute to reducing the environmental impact of the building sector.

Sharing solutions. Digitalisation has transcended property borders in terms of management and use of spaces. Examples of intermediation services such as WeWork and AirBnB, indicate how alternative ways of forming properties can create new models for how spaces are used (McLaren, 2016). The way we currently use spaces and services is based on ownership and not accessibility, but sharing solutions have the capacity to emphasise the value of use rather than possession. Moreover, as discussed with Consultant Z, sharing solutions have the potential to introduce new ways of using space by engaging property owners, tenants and users alike. Currently, resource-efficient use of space is not widely included in the sustainability agenda of real estate actors in Stockholm (Fastighetskontoret, n.d.). Sharing solutions offer the possibility to create new partnerships that increase the volume of resources available to all the parties involved. The reduction of embodied impacts could therefore act as a key measurement to promote sharing solutions.

Existing building stock. “New production” has been the main area of expertise and innovation in the modern building industry. The expectations on the design of new objects often shape the training of architects and engineers, in what Kohler & Hassler (2002) describe as “a modern value system”. On a larger scale, these expectations may strongly influence policy by e.g. leaving “the existing” out of the discussion. A change of perspective would require review and development of broader professional competence to deal with existing buildings.

Several studies indicate that the mortality of buildings relies on their loss of value rather than only on their age (e.g Aksözen et al., 2017; Thuvander et al., 2012). In order to decrease new construction, existing buildings need to be preserved. One way to ensure this is through renovations. The implementation of the proposal would contribute to boost the renovation market, which could contribute to the targets of decarbonisation of building stocks and to the creation of new jobs.
Moreover, real estate owners would have new opportunities to diversify their offer of commercial space, while adding value to their properties through a more efficient exploitation. Tenants at the same time would be encouraged to develop their business models from a sharing economy perspective, with increased flexibility/affordability/availability of space as an incentive.

In principle, the formation of 3D properties for a resource-efficient use of existing space might only be relevant in places under conditions of population growth and where real estate is considered as an asset whose value is maintained. If existing buildings would have a short lifespan or if the quality of the construction would be poor, it would be difficult to motivate investments in the existing rather than in new constructions. Furthermore, in a scenario where the population shrinks, spaces would become vacant naturally. Countries like Japan currently face both conditions (The Japan Times, 2017).

Urban morphology plays an important role regarding the capacity to create the necessary volume for sharing solutions. In dense urban blocks, more properties can be merged and the demand for mixed use spaces might be easier to capture. In detached constructions in suburban areas, the available floor area might be limited and the demand can be difficult to create.

In order to plan for a more efficient use of space, indicators and measurements are necessary to understand why it is not efficiently used. The first step in this process should be to measure the existing capacity and to evaluate whether there is room for optimisation. However, the interviews and other sources used in this study point to a lack of data available to the various stakeholders. Open data would be one fundamental feature in a sharing city, as it would enable a broader range of actors to visualise the current situation in terms of supply and demand, and to come up with new solutions based on this information. Data is crucial for both developing new services and management, as well as to inform land use policies. In order for the city to more effectively steer the demand for space, it should have accurate and updated data about the existing building stock as a basis for decision-making.

POLICY RECOMMENDATIONS

Plans for the existing building stock could be formulated based on targets that spark innovation such as “providing XX% of new space within the existing building stock”. New constructions should also be based on optimisation strategies.

If decreasing new construction would be prioritised in urban development agendas, the creation of reliable data sources such as BIM models of existing buildings would be needed in order to plan for it. This could be done through partnerships with owners, as well as policy instruments such as subsidies.

FURTHER RESEARCH

During the inquiry many other questions arose regarding measurements of use of space, development of sharing solutions and property rights. I compiled some of them as suggested topics for further research, including:

- The design and development of sharing solutions for spaces from a resource-efficiency perspective. Measurements and estimations of the actual savings in energy consumption and GHG emissions suggested in the proposal as well as various aspects regarding its technical feasibility and their impact on land value and affordability of housing. Incentives?
- Taking the "year" as the reference unit in order to capture temporal "lock-ins" such as summer time and be able to study changes and patterns of occupancy. What if they would be dissolved and re-configured?
- Implications of changes in working hours and new "calendars" (e.g. 3 x 3 systemet) and their impact on demand / supply of space.
- Comparative studies in ownership, management and property formations in other contexts. What could be the possibilities in other legal systems? Other relationships between property formations and use of properties.
- 4D properties? In a scenario of increased demand for sharing solutions in the future, 4D properties might become a necessary instrument to guarantee real rights in space and time. They might even be independent from a specific location. What would be the need and relevance of including "4D properties" in a cadaster e.g. for taxation purposes? What data would be needed? How to describe and delimit a 4D property?
References


Reynolds, J., & Sundström, M. (2014). Digitalisation, retail transformation and change: what will European consumers want from their future shopping centre experience?.


Appendix

Appendix 1. Interviews
Appendix 2. Spreadsheet
Appendix 3. Opening hours
Appendix 4. Calculations
Appendix 1. Interviews

The names of interviewees and companies are anonymised.

1.1 Phone interview with ANALYST Z

Date: 03.09.2018
Duration: 30 min
Topics / questions:

- What are the main reasons to establish a 3D property?
- What are the benefits of 3D properties
- How were mixed-use projects managed before the introduction of 3D properties?
- What are the current trends in the market regarding 3D properties?
- Current trends in commercial real estate market in Stockholm

1.2 Interview with EXPERT Y

Date: 11.09.2018
Duration: 60 min
Topics / questions:

Planning process
- Detail plan vs. geometric constraints and zoning. Heights and distances
- Property rights and demand for space

3D properties. 3D/4D cadaster
- What possibilities have 3D properties created that did not exist before?
- Evolution of number of 3D properties, trends
- Purposes of 3D properties
- 4D cadaster? Time share, use of space?

Data
- Cadastral data, is something lacking in your opinion?
- Any examples of 3D cadaster? Or 4D cadaster?
- Time share apartments, how are they registered in terms of property rights

1.3 Interview with MANAGER A

Date: 03.10.2018
Duration: 60 min
Topics / questions:
DATA
How well do you know your properties?
What do you measure/monitor and how? Data from facility management and how is it used? Do you measure the use of space/resources? What data do you have on your building stock? Do you have all your properties in BIM? How do you assess/establish targets?

PARTNERSHIPS
Do you have any alliance with other property managers? E.g. with the increased demand for hotels?
Forum for Sustainable Real Estate, findings, learnings, exchanges.
Partnerships for a more efficient use of resources? How are they created? How could they be created?

PROPERTIES
Do you have any 3D properties?
Type of contracts? Type of clients, big or small companies/organizations?
Current initiatives for sharing solutions. Are they motivated by your corporate sustainability policies?
Location/typology of the properties - corporate/branding.

EXPERIENCES
What is your approach to sharing solutions?

BUSINESS
Do your properties challenge business models/tenant activities?
Are sharing solutions in conflict with your business model? “Rent out as much as possible”? Or how can it create value?
Areas of opportunity, further research, pilot projects. Main barriers/obstacles for sharing solutions.
Is there a pilot project you would like to develop? Main barriers/obstacles for sharing solutions.

1.4 Interview with MANAGER B

Date: 03.10.2018
Duration: 60 min
Topics / questions:

DATA
Do you measure the use of space/resources? What data do you have on your building stock? Do you have all your properties in BIM? Data from facility management and how is it used?

PARTNERSHIPS
Partnerships for a more efficient use of resources? How are they created? How could they be created? Type of contracts? Type of clients, big or small companies/organizations?
Do you have any alliance with other property managers? E.g. with the increased demand for hotels?

PROPERTIES
Image of the properties - corporate/branding. Are the activities of tenants a criteria for the management of your properties? Do your properties challenge business models/tenant activities?
Most of your properties are located in suburban settings and are detached buildings. How are these locations chosen? Criteria such as land value/budget, urban structure. Do you have any 3D properties?

EXPERIENCES
Current initiatives for sharing solutions. Are they motivated by your corporate sustainability policies?

BUSINESS
Are sharing solutions in conflict with your business model? "Rent out as much as possible”? Or how can it create value?
Is there a pilot project you would like to develop? Main barriers/obstacles for sharing solutions.

1.5 Interview with CONSULTANT Z

Date: 09.10.2018
Duration: 60 min
Topics / questions:

DATA / MEASUREMENTS IN A SHARING ECONOMY
Furniture and equipment vs. built area
Construction materials + furniture and equipment

SUCCESS FACTORS
How can spaces [use of] challenge business model and consumption patterns?
Property rights [!], measurements?

REBOUND EFFECTS
Sharing solutions of space, rebound effects?
Consumption and production of space. [land value]

STAKEHOLDERS - TRENDS
Different stakeholders - municipalities. Partnerships ?
Role of ownership in a sharing economy. Management?
Appendix 2. Spreadsheet

- MAIN SPREADSHEET
- CATEGORIES (Goods, Food, Services, Offices)
Appendix 3. Opening hours

- MAIN SPREADSHEET

- CATEGORIES (Goods, Food, Services, Offices)
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**Occupancy (%)**

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**Notes:**

- Hours per day and per week are calculated based on the occupancy and capacity data provided.
- The table above reflects typical hours for each day of the week, with varying numbers for each position.
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<th>Trade Area</th>
<th>Weeks</th>
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<th>Avg Sales</th>
</tr>
</thead>
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<td></td>
<td>Hours per day (h)</td>
<td>Occupancy (%)</td>
<td>Area (m²)</td>
</tr>
<tr>
<td>--------</td>
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<td>170</td>
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</tbody>
</table>

|        | Total | 52.67 | 31.84 | 59.23 | 83.5 | 567762.5 |

**Average**

<p>|        | Total | 52.67 | 31.84 | 59.23 | 83.5 | 567762.5 |</p>
<table>
<thead>
<tr>
<th></th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
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<td>4</td>
<td>5</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

**Hours per day (h):**

- Mon: 0
- Tue: 2
- Wed: 3
- Thu: 4
- Fri: 5
- Sat: 6
- Sun: 0

**Hours per week (h):**

- Mon: 0
- Tue: 2
- Wed: 3
- Thu: 4
- Fri: 5
- Sat: 6
- Sun: 0

**Total:** 21

**Average:** 3.0

**Area (m²):** 867

**Capacity (m²h):** 33967

**Notes:**

- Occupancy (%): 173.1
- Capacity (m²): 33967

**Areas:**

- Total: 867
- Area: 173.1
Appendix 4. Calculations

**CALCULATIONS**

\[
\text{CURRENT CAPACITY} = \frac{\% \times \text{proportion of used capacity}}{\text{MAXIMUM CAPACITY}}
\]

"CAPACITY" refers to used space \( \times \) time.
* space = floor area (m²)
* time = opening hours (h)

\[
\text{A} = \frac{120 \text{m}^2 \times 32 \text{h}}{180 \text{m}^2 \times 168 \text{h}} = \frac{5,760 \text{m}^3}{30,240 \text{m}^3} = 0.19 \rightarrow 19\%
\]

\[
\text{B} = \frac{60 \text{m}^2 \times 20 \text{h}}{60 \text{m}^2 \times 168 \text{h}} = \frac{1,200 \text{m}^3}{10,080 \text{m}^3} = 0.12 \rightarrow 12.5\%
\]

\[
\text{C} = \frac{40 \text{m}^2 \times 45 \text{h}}{40 \text{m}^2 \times 168 \text{h}} = \frac{1,800 \text{m}^3}{6,720 \text{m}^3} = 0.27 \rightarrow 26.5\%
\]

\[
\text{D} = \frac{34 \text{m}^2 \times 15 \text{h}}{34 \text{m}^2 \times 168 \text{h}} = \frac{510 \text{m}^3}{5,184 \text{m}^3} = 0.09 \rightarrow 9.5\%
\]

\[
\text{E} = \frac{45 \text{m}^2 \times 23 \text{h}}{45 \text{m}^2 \times 168 \text{h}} = \frac{1,305 \text{m}^3}{7,560 \text{m}^3} = 0.17 \rightarrow 17.3\%
\]

\[
\text{Z} = \frac{(\text{A}) + (\text{B}) + (\text{C}) + (\text{D}) + (\text{E})}{\text{180 m}^2 \times 168 \text{h}}
\]

\[
Z = \frac{5,760 \text{m}^3 + 1,200 \text{m}^3 + 1,800 \text{m}^3 + 510 \text{m}^3 + 1,305 \text{m}^3}{105,300 \text{m}^3} = 0.348 \rightarrow 34.8\%
\]

\[
\text{A'} = \frac{\text{A} + \text{AB} + \text{AC} + \text{AD} + \text{AE}}{\text{180 m}^2 \times 168 \text{h}} = \frac{76,30 \text{m}^3}{30,240 \text{m}^3} = 0.25 \rightarrow 25\%
\]