THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Spatial Design for Circularity

Exploring Spatial Aspects in Housing Design
with Focus on the Kitchen

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Cover: Spatial characteristics of kitchens that are important
for establishing a circular residential building stock

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Abstract

The building industry and especially multiresidential buildings are responsible for a large portion of environmental impact, energy use and resource exploitation. Hence, there is a need to shift towards more sustainable design solutions for such buildings, which might be achieved by adopting circular economy strategies. This thesis develops knowledge on how to formulate solutions for circular housing design by analysing problematics connected to one important function of dwellings, the kitchen. This part of the home is subject to frequent renovations and extensive material flows driven by regulations, design trends and end-user preferences. Previous research has investigated kitchen-related issues in connection with circularity, including resource use, furniture design or food waste. However, there has been little investigation in connection with the spatial design of kitchens despite earlier studies indicating the importance of spatial configurations to a sustainable built environment. Therefore, this Licentiate thesis explores the spatial design of the kitchen with the aim of increasing circularity in residential building design.

To understand the complex sociomaterial phenomenon regarding kitchens, this thesis reports on two studies. Study 1 examines the social agencies through investigating the value chain of kitchens. Taking a qualitative approach, this study aims to understand stakeholder perspectives on how kitchens are commissioned, designed, built, delivered, and installed. This is followed up by Study 2, which explores the material agencies by evaluating the adaptive capacities of 3,624 kitchens in contemporary apartments. The goal was to summarise current design strategies regarding kitchens and investigate the opportunities that adaptable spatial design presents to circular housing design.

The results showed that spatial design is one important factor in connection with circularity. In both studies, spatial qualities and characteristics were identified as enablers in achieving a circular housing design and built environment. The design of spatial characteristics, such as room size, room typology, kitchen typology, windows and infrastructures might enable more adaptability of dwellings which, in turn, would support less frequent, low-impact alterations of the room. The main contribution of this thesis is in recognising those spatial characteristics which are important to consider when creating a future circular kitchen design. These characteristics need to be detailed and it is important that upcoming studies further investigate end-user perspectives.

In conclusion, this thesis contributes to the ongoing development of a circular building industry by presenting knowledge on circular opportunities for the built environment and highlighting adaptable spatial design as an important factor in circular housing design.

Keywords: circular economy, circular design, housing design, adaptability, spatial design, kitchen, value proposition, sociomateriality

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Included publications

PAPER 1

[Journal Paper] Ollár, A.; Femenías, P.; Rahe, U.; Granath, K. (2020) *Foresights from the Swedish Kitchen: Four Circular Value Opportunities for the Built Environment.* Sustainability, 12, 6394. https://doi.org/10.3390/su12166394

Contributions: The workshop was carried out by the research group (including A.O., P.F., and U.R.) of the CIK project. The interviews were planned and performed by A.O. and P.F. The focus group session was organised and carried out by P.F. and U.R. All audio recordings were transcribed by a team coordinated by A.O. The analysis of the empirical material was conducted by A.O. The four authors developed the outline of the paper together. The writing process was led by A.O. As supervisors, P.F., U.R., and K.G. reviewed and edited the paper.

PAPER 2

[Journal Paper] Ollár, A.; Granath, K.; Femenías, P.; Rahe, U. (2021, submitted) *Is there a need for a new kitchen design? Assessing the adaptative capacity of space as an enabler for circularity in multiresidential buildings.*

Contributions: K.G. provided the permitted documentation on the housing projects. A.O. reviewed and sampled the material, identified the spatial characteristics from the literature, developed the analytical framework and performed the analysis. K.G. advised on ambiguous decisions related to the floorplan study. The four authors collectively developed the conceptual outline of the paper. The writing process was led by A.O. As supervisors, P.F., K.G., and U.R. helped fine-tune the analytical framework and reviewed and edited the content of the paper.

Additional publications & conference contributions

[Journal Paper] Hagejärd, S.; Ollár, A.; Femenías, P.; Rahe, U. (2020) *Designing for Circularity - Addressing Product Design, Consumption Practices and Resource Flows in Domestic Kitchens.* Sustainability, 12, 1006. https://doi.org/10.3390/su12031006

[Conference Presentation] Ollár, A.; Femenías, P.; Rahe, U. (2019) *What shaped the Swedish kitchen? A historical overview to plan for further development.* NAF Symposium 2019 in Gothenburg - Approaches and Methods in Architectural Research, 13-15 June 2019 Gothenburg, Sweden.

[Conference Presentation] Ollár, A.; Bengtsson, M.; Femenías, P. (2019) *The kitchen of the future through an academic lens: An architectural thesis project's knowledge contribution to academic research.* The 11th Annual Symposium of Architectural Research, 3-4 October 2019 Tampere, Finland.

[Extended Abstract] Andersson, S., Ollár, A., Femenías, P., & Rahe, U. (2018). *Retrofitting from the Inside/Insight Perspective: Adapting to Users' Needs with the Kitchen as a Starting Point.* Retrofit Europe! Innovation meets market SBE19 Conference, 5-6 November 2018 Eindhoven, The Netherlands.

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1. Introduction

Within the built environment, multiresidential buildings represent a considerable segment, 49% of residential buildings in the EU (European Commission, 2020) and 51% of the housing stock in Sweden (Statistics Sweden, 2019). Furthermore, these types of buildings are responsible for a large portion of environmental impact related to buildings (Nemry et al., 2010). Hence, it is important to develop strategies and design solutions for more sustainable multiresidential buildings. The circular economy (CE) was found to be a potential tool (Pomponi & Moncaster, 2016) in addressing sustainability issues in the built environment. Therefore, this thesis examines what a CE would mean for multiresidential buildings, by investigating one function of the home – the kitchen.

1.1. Background

The linear processes of the building sector consume 40% of the global virgin material extractions (Khasreen et al., 2009), account for 30% of greenhouse gas emissions (Word Economic Forum, 2016) and produce 40% of the waste worldwide (Ness & Xing, 2017). Furthermore, the linear model of "take-make-dispose" contributes to the premature obsolescence of still-functioning building products and components (Arora et al., 2020). Achieving the Sustainable Development Goals set for the built environment (United Nations, 2015) requires a shift to new processes.

Governmental bodies recognised this need and turned to the concept of CE which provides strategies (such as share, maintain, reuse, refurbish and recycle resources) which would prolong product lifespans and reduce waste production (Ellen MacArthur Foundation (EMF), 2015). There is also evidence showing that transitioning to a CE in the building industry can contribute to economic (new businesses, increased revenue) (EMF, 2015), environmental (decreased raw material extraction and environmental pollution) (Hossain & Thomas Ng, 2019; Manninen et al., 2018; Nußholz et al., 2020) and social sustainability (new job opportunities, increased wellbeing and equality) (Su et al., 2013). Initiatives have therefore been formulated, such as the Swedish Climate Act (Government Offices of Sweden, 2017), the European Green Deal (European Commission, 2019) and the Circular Economy Action Plan (European Commission, 2020).

Adapting to the new demands posed by regulations and governmental initiatives, researchers have developed frameworks and strategies to enable CE in the built environment (Cheshire, 2016; Eberhardt et al., 2020; Göteborgs Stad, 2020). Within these frameworks and strategies, adaptability has been recognised as a key feature of buildings. Through adaptability, the lifespan of buildings and building components may be extended and material flows connected to renovations reduced (Geldermans et al., 2019a). The environmental impact of the building sector might be also mitigated since adaptability restrains premature

obsolesce and extensive high-impact retrofits (Kendall, 1999; Slaughter, 2001). Furthermore, adaptability closely relates to the design of space and spatial functionality as an important issue in housing design, which, according to West & Emmitt (2004), is often overlooked. West and Emmitt (2004) conclude that, as a result, contemporary housing design fails to provide adequate room dimensions or functional spatial design, resulting in uncomfortable or unusable spaces. This, in turn, leaves little margin for households to adapt the space to their needs and the lack of adaptability "undermines the longlivity [sic] of the housing stock" (Braide, 2019, pp. 163). Lee (2020) also pointed out that spatial configurations are an essential aspect of sustainable architecture which is currently understudied.

Researchers have recognised that a next step on the way towards a CE is to develop circular design solutions for individual functions of buildings (Akanbi et al., 2018; Cambier et al., 2020; Cheshire, 2016; Pomponi & Moncaster, 2017). This is important since buildings consist of many layers with different lifespans (Brand, 1994) and design solutions should be developed to target particular building functions or elements and match their varying lifespans. In this Licentiate, the kitchen was chosen as a subject for studying building function-related circular design solutions since it is an important part of the home and the centre of food-related and social activities (Willén, 2012). During the past century, this room has undergone substantial physical changes and been shaped by social transformations, altering the appearance and function of the space (Thörn, 1994). It is currently a problematic area in dwellings and has a significant impact with regard to frequent alterations (Hand et al., 2007; Judson et al., 2014; Maller et al., 2012), energy use (DEFRA, 2013; Heller & Keoleian, 2000), resource use (Hagejärd et al., 2020) and material flows (Femenías et al., 2018). In Europe, up to 90% of discarded furniture (including kitchens) is incinerated or deposited in landfill (European Remanufacturing Network, 2015). Additionally, the average service life of the kitchen (seven years) is below its functional lifetime (Shove et al., 2007). One cause of the short lifespan of kitchens is premature renovations driven by design trends, regulations, inadequate quality of built-in materials, end-user preferences and secondary renovations (Femenías & Geromel, 2019). Research has estimated that premature renovation connected to kitchens may be responsible for about 57% of the overall climate impact (measured in CO_2 equivalent over a 15-year period) of internal alterations and maintenance of condominiums (Femenías et al., 2018). The frequency of kitchen alterations indicates that current housing design does not satisfy end-user needs and that the associated major impact of renovations results in increased material flows and resource use (Femenías et al., 2018).

This thesis builds on previous research investigating residential design (Nylander et al., 2019), adaptability (Braide, 2019; Femenías & Geromel, 2019) and circular solutions for kitchens. In earlier studies, CE and circular design have been explored to improve the kitchen's performance. These investigations encompassed topics such as the resource efficiency of households (Hagejärd et

al., 2020), financial models (Wouterszoon Jansen, van Stijn, Gruis, & van Bortel, 2020) or the development of tools to create circular building components (van Stijn & Gruis, 2019). However, there has been a lack of spatial investigation in relation to this function of buildings, specifically in connection with adaptability and circularity. This research, therefore, explores the role played by adaptable spatial configurations in connection with circularity, using the kitchen as a starting point for explorations.

In describing the kitchen as a function in homes, this thesis takes inspiration from three concepts. Firstly, in the framework of the sheering layers from Brand (1994), the kitchen may be identified as an element bordering the categories of "space plan" and "stuff". Secondly, within the distinction of architectural products by Jager (2002), the kitchen may be defined as an assembly of individual sub-components (such as built-in furniture, appliances, flooring and so on), which together form the architectural space. Thirdly, the open building concept embraces the theories of adaptable buildings by Habraken (1972), which advocates for a building typology distinguishing between structural (support) and interior (infill) elements. In this concept, the kitchen may be seen as both an infill (interior products) and a support (layout, walls, floor, facade). Expanding on and combining these concepts, in this thesis, the kitchen as a function is defined as the three-dimensional enclosure of the space containing the function associated with the kitchen. This includes not only independently manufactured products and the assembly of them but also the layout and the space of the room.

1.2. Research focus and questions

The overall purpose of this PhD research is to contribute to more sustainability in the home environment. The aim is to explore the spatial aspects of circularity in residential buildings with special focus on the kitchen. This has been done through studies investigating what kinds of kitchens are currently designed, produced, and installed in homes and how are these activities carried out. Through investigating what is currently available, the intention was to identify aspects that need to be improved to achieve a future CE-compatible spatial design for the kitchen.

This thesis addresses three main research questions (Table 1). Two of them are connected to the two studies of this Licentiate, while the third answers an overarching question framing the whole thesis. The two main lines of enquiry at the centre of this thesis aim to assess the circular capacity of current kitchen design, understand why contemporary kitchens are designed and produced as they are (focusing on value creation for different stakeholders) and analyse current kitchen designs (focusing on spatial aspects and adaptability).

Firstly, the stakeholder perspectives and value chain of the kitchen were studied with the goal of identifying circular value opportunities (Study 1). This

study aimed to answer the research question *'How do circular values relate to the current production processes and stakeholder perspectives of the kitchen?'*.

Secondly, the spatial characteristics of the kitchen were investigated, in order to understand their role in the context of CE and create a descriptive summary of important spatial characteristics that need consideration if a CE-compatible spatial design is to be achieved (Study 2). This study addressed the research question of *'How might spatial characteristics contribute to a circular kitchen design?'*.

In addition to these two studies, this Licentiate employs sociomateriality as a post-reflective framework (explained in detail in Chapter 4). With the help of this framework the outcomes of the studies and the social and material agencies of the kitchen are discussed through answering the research question *'How might a circular kitchen design be understood from a sociomaterial perspective?'*.

Table 1 – Summary of the research questions addressed in this thesis

Function	Identification	Question	Studies
Study-specific question	RQ1	How do circular values relate to the current production processes and stakeholder perspectives of the kitchen?	Study 1
Study-specific question	RQ2	How might spatial characteristics contribute to a circular kitchen design?	Study 2
Overall question	RQ3	How might a circular kitchen design be understood from a sociomaterial perspective?	Studies 1 & 2

1.3. Research approach

The field of architectural research "encompasses a relatively wider diversity of substantive foci and methodological choices" (Groat and Wang, 2013, pp. 4). The nested framework of Groat and Wang (2013) helps academics navigate this vast research field and find appropriate methods for the focus and subject of their research. The nested framework consists of four frames: (1) systems of inquiry (set of assumptions or worldviews), (2) school of thoughts (theoretical perspectives), (3) strategies (research design) and (4) tactics (specific methods). Figure 1 illustrates how the research approach of this thesis is situated within the nested framework.

The phrase "systems of inquiry" refers to the set of assumptions or worldviews "that serve as the [ontological and] epistemological basis for any research study" (Groat and Wang, 2013, pp. 14). There are many frameworks for understanding systems of inquiry. The dichotomous model distinguishes between quantitative and qualitative approaches (Groat & Wang, 2013). Within the quantitative approach, the researchers position themselves in an objective reality, independent of the subject. A qualitative approach, on the other hand, presumes a subjective reality and a researcher who interacts with the investigated

context. Expanding this model, Groat and Wang (2013) proposed a Three-Part Continuum. At either end of the continuum stands the positivist approach (quantitative) and constructivist approach (qualitative). At the middle of the continuum, Groat and Wang (2013) established the intersubjective approach. This is defined ontologically by diverse realities situated in a sociocultural context in which shared understandings of those realities are possible. Epistemologically, it places the researcher in a sociocultural engagement, in which objectivity is neither possible nor desirable. The Intersubjective approach "recognize[s] the significance of values and meaning in framing the goals of the research and/or interpreting the results" (Groat and Wang, 2013, pp. 78). Furthermore, this approach acknowledges that beyond rational causalities lie relationships and interactions which are important to consider when studying any phenomenon. These relationships and interactions must also be explained in a social or historical context.

The research presented in this thesis embraces an intersubjective approach. Within this approach a sociomaterial school of thoughts have been applied to further define the ontological and epistemological grounds of this thesis (detailed in Chapter 4). To study the sociomaterial phenomenon of the kitchen, a mixed methods research strategy has been used (detailed in Section 5.1), with quantitative and qualitative tactics (detailed in Section 5.2 and 5.3).

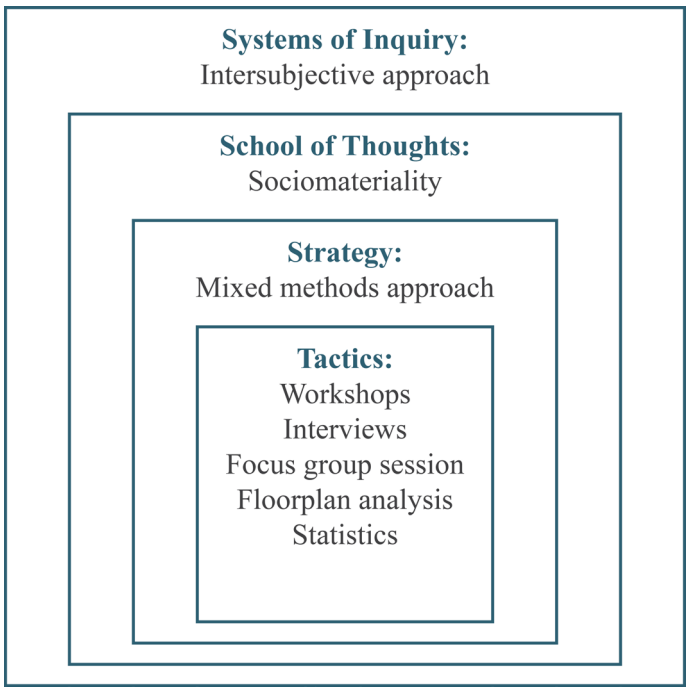

Figure 1 – Positioning the PhD research approach (in black) in the nested framework (in colour) of Groat and Wang (2013)

1.4. Delimitations

The studies part of this thesis examined the design and building processes connected to kitchens in multiresidential housing, in a Swedish urban context. Globally, an increasing portion of the population resides in and around urban settlements (Statistical Office of the European Communities, 2016). This is also reflected in the significant portion (51% of the housing stock) of rental and owner-occupied apartments in Sweden (Statistics Sweden, 2019). This context has influenced the generalisability of the results, which are discussed in Section 5.4.

This thesis does not address questions connected to environmental studies, economic issues, or specific building technologies. The investigations are limited to analysing and evaluating contemporary patterns and identifying major spatial aspects that need further study and definition. The historical overview of the Swedish kitchen (Section 2.1) merely aims to give an insight into the long tradition of housing and kitchen research in Sweden and was used to narrow the focus of the research. Additionally, this thesis focuses on the stakeholders involved in the design and building processes and the kitchen as a room; a deeper evaluation of the needs and perspectives of the end-users is not included. Investigating end-user demands and formulating exact design strategies are planned as part of the second part of the PhD.

1.5. Research context

This research is part of the Circular Kitchen (CIK) research project funded by EIT-Climate-KIC and Centrum för boendets arkitektur (CBA). The project is being conducted in collaboration with academic (TU Delft) and industry partners (kitchen producer, housing developer and appliance producer). The activities involve theoretical knowledge-building and developing, prototyping, and testing new CE-based kitchen designs and accompanying business models. The main goal of the project is to find novel solutions to design, test and disseminate circular kitchens that are: (1) built of renewable and recyclable materials, (2) are easy to repair, refurbish, assemble and disassemble, (3) reduce resource use, consumption and waste generation and (4) are economically competitive with current products. Furthermore, the project examines how people use their kitchens, which kitchen-related behaviour patterns may be identified and how modern lifestyles affect the use of the kitchen (Hagejärd et al., 2020). The main methods are co-creation workshops with the industry partners, empirical user studies (interviews and workshops) with the public and prototyping (building, testing, and evaluating the developed design at several stages). This project served as a “test bed” and data collection opportunity for my research which contributes with investigations into how the spatial design of the kitchen may support or hinder circularity in the home environment.

1.6. Terminology

In this thesis, some terms are used in a particular way or with a specific meaning. These are clarified in Table 2.

Table 2 - Collection of important terminology applied in this Licentiate

Term	Explanation
Adaptability	The value of "inherent properties in a building that gives [sic] it the ability to change, or the relative ease with which it can be changed" Heidrich et al. (2017, pp. 287).
Adaptive capacity	A metric to measure a buildings ability "[…] to cope with future changes with minimum demolition, cost and waste and with maximum robustness, mutability and efficiency" (Sinclair et al., 2012, pp. 40).
Combined kitchen-living room	A room which includes the kitchen and living room in one open space.
Kitchen	The three-dimensional enclosure of the space containing the functions associated with the kitchen.
Kitchen typology	The layout of the built-in furniture, that influences the spatial use and experience of the room (straight-kitchen, L-kitchen, parallel-kitchen, U-kitchen).
Open floorplan	A spatial design whereby the kitchen and living room are part of one open space.
Room typology	As defined in Hillier, 2007, pp. 250-251: A: "dead-end" room; B: "pass-through" room; C: room in a single ring; or D: room that is part of more than one ring.
Spatial characteristic	Characteristics of a spatial unit (e.g., room) that influence how it may be used, furnished, and experienced (e.g. size, length and width of room, door and window openings, fixed equipment, infrastructure outlets).
Value chain	A set of activities involving a network of stakeholders participating in the value creation of a certain product or service.
Value mapping	A tool to identify three types of values: value captured, value missed destroyed or wasted and value opportunities.
Work surface	Horizontal surfaces at a comfortable height, used for processing and preparing food (e.g. free countertop surfaces or additional tables in or close to the kitchen).
Workstation	Units forming part of the built-in furniture which have designated work functions (e.g. sink, stove, fridge, or work surface).

1.7. Outline of the Licentiate thesis

The rest of this Licentiate thesis is structured as follows. In Chapter 2, a historical overview explains the evolution of the Swedish kitchen and connected research approaches. Chapter 3 describes the important concepts and previous investigations in relation to the research areas connected to this thesis. Chapter 4 introduces the theoretical framework (sociomateriality). Chapter 5 explains the

mixed methods used in connection with the two studies. Chapters 6 and 7 summarise the results of Studies 1 and 2. Chapter 8 formulates the discussion. Conclusions are drawn in Chapter 9 and Chapter 10 outlines further research pathways. The two papers which form this Licentiate thesis are appended at the end of the booklet.

2. Extended background

This thesis examines the kitchen as an important part of homes. A historical overview is presented, to better understand the reasons behind contemporary kitchen designs. As described in Section 1.4, the focus is laid on the Swedish context. Hence, the overview describes the development of the Swedish kitchen over the past century. This material is based on the unpublished manuscript presented at the NAF Symposium in 2019.

Earlier studies have investigated the development of the Swedish kitchen over time, usually through chronological analysis. However, the analytical perspective may be different. Some give a comprehensive historical overview of events (Nylander, 2013, 2018; Snidare, 2004; Torell et al., 2018) and some analyse a specific concept or phenomenon (such as food scarcity, furniture design, spatial design) within the development (Ledin & Machin, 2018; Stigzelius, Araujo, Mason, Murto, & Palo, 2018; Willén, 2012). The next section provides a holistic chronological overview without focusing on any specific concept or phenomenon.

2.1. The Swedish kitchen – A historical overview

1900s

During the second half of the 19th Century industrialisation all over Europe attracted a workforce from the farmlands to the cities which surrounded factories. This urbanisation brought pressure for bigger settlements. The demand for housing was rising rapidly, leading to crowded living conditions and high rents (Lee, 2018). The situation escalated to the point where people even rented out their bench sofas in the kitchen. To tackle this issue, there was some experimentation with collective living, kitchenless homes and shared kitchens (Lee, 2018). In the USA, Charlotte Perkins Gilman was inspired by the collective living idea and proposed a new typology of dwelling: the apartment hotel with common dining space, social services, and childcare facilities. Her vision of emancipating women from the burden of domestic labour was manifested by innovating what future home settings might become. In Stockholm, similar to Gilman's proposal, collective houses were built (such as on Östermalmsgatan or a few decades later the Markelius house on John Ericssonsgatan). These houses had apartments without a kitchen and tenants could order breakfast, lunch, and dinner from a central kitchen in the basement through an internal telephone system.

For the working-class, the beginning of the 20th Century was defined by low-quality dwellings, with people living in overcrowded apartments (Nylander, 2013). A working-class family typically shared a one-room apartment. In Gothenburg, this kind of apartment was built in the form of the so called "landshövdingehus" (governor houses, example floorplan in Figure 2) (Movilla Vega & Hallemar, 2017). The flats consisted of two general rooms (one of which

was used as the kitchen) with no built-in furniture or water supply. The question of hygiene in cities became a pressing issue since running water, bathrooms and toilets were absent from these dwellings.

In the bourgeois and upper-class apartments of the time, the reception rooms faced the street while the private areas and kitchen faced the courtyard. The kitchen was hidden away, as it was dirty and noisy. A servant entrance ensured that all deliveries and dealings with the water supply in the courtyard took place without disturbing the homeowners. The lack of domestic help at the beginning of the 1900s was a contributory factor to the reform of the kitchen (Lee, 2018). Contemporary building and kitchen layouts were designed based on the assumption that there would be domestic help; performing kitchen-related activities in such layouts became tiresome without them.

The government started the "egnahemslånefonden" (the State Home Ownership Fund, 1904) to give the working-class its own housing and draft designs for more modern kitchens (Lee, 2018). As part of these government initiatives, a series of building inspections began in 1906, to evaluate the condition of people's housing. These initiatives show that the government was aware of the housing and health crises and tried to address the issues.

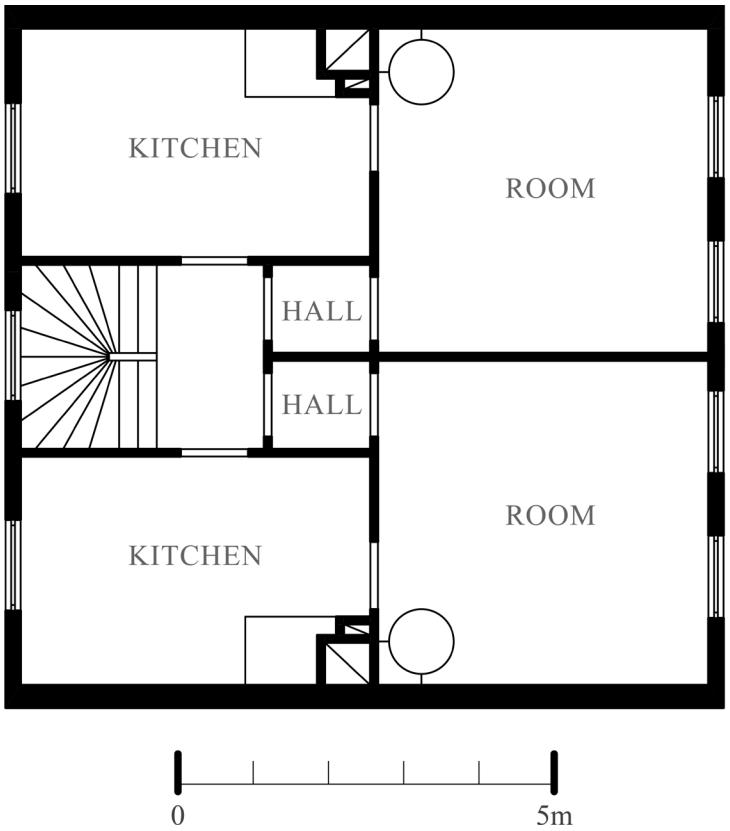

Figure 2 – Landshövdingehus floorplan from Gothenburg, 1885 (adapted from Almqvist, 1940, pp. 13). The two rooms in each apartment are general. The fireplace in the larger room indicates a living room function and the other room was used as a kitchen.

1910s

At this period, the role of women was regarded as the one responsible for household chores and facilitating a home environment in which their men could rest and not worry about existential issues (Lee, 2018). Therefore, rationalising household chores gained more and more attention among women and publications such as Christine Fredricks' books (1913 - *The New housekeeping*, 1919 - *Household Engineering*) spread guidance and advice on how to minimise the hours spent on domestic work. Fredricks' work gained significant publicity and was translated into several languages and distributed all around Europe.

Infrastructural developments expanded around Sweden. Electricity, gas and running water were installed in some newly built dwellings. However, it took another 50 years until these systems were available in most households (Lee, 2018). Other technological advances such us irons and toasters arrived in people's homes.

The government initiated a national inventory of the housing stock, which was then repeated regularly. The enquiry focused on the size of apartments, state of the kitchen, central heating, water and sewage system, toilets, bathroom and how many were living in each dwelling (Lee, 2018). The Kommittén angående bostadssociala minimifordringar (the National Committee for the Minimum Requirements in Social Housing) was set up in 1919. This committee established norms and recommendations for working-class dwellings in their report *Praktiska och hygieniska bostäder* (Practical and Hygienic Dwellings) (Movilla Vega & Hallemar, 2017). These dwellings were modelled after the landshövdingehus and were only 40-45 m^2 per family.

1920s

In 1926 the now famous Frankfurt kitchen (Figure 3) was designed by Margarete Schütte-Lihotzky for social housing projects (Nowakowski, 2015; Thiberg, 1994). It was a fitted kitchen with parallel furniture sides dedicated to minimising effort and carrying out tasks at maximal efficiency, thanks to short distances between workstations (Nowakowski, 2015). This kitchen typology was installed in about 10,000 households during the 1920s in Frankfurt and several variations of it later appeared in homes all around Europe. This kitchen typology is no longer built since it was usually small, dark, only large enough for one person to use, designed with limited work surfaces and not optimal for socialising (Nowakowski, 2015). The München kitchen was developed at the same time (Lee, 2018). In contrast to the Frankfurt kitchen this kitchen was more of a kitchenette in the living room. These two kitchen typologies represented two views of the role of women. While the München kitchen supported social and family life, the Frankfurt kitchen created a productive and functional role for housewives (Lee, 2018). The fact that the Frankfurt kitchen typology was more popular, reflected the wishes and demands of the society of that time.

It was not only the layout and organisation of the kitchen that received attention. The Hoosier cabinet and its Swedish version named after Kajsa Warg (1925) revolutionised the furniture design of the kitchen (Lee, 2018). This piece of furniture incorporated storage and a work surface in the same space and most

of the equipment and ingredients were within arm's reach, minimising time and saving energy for the user.

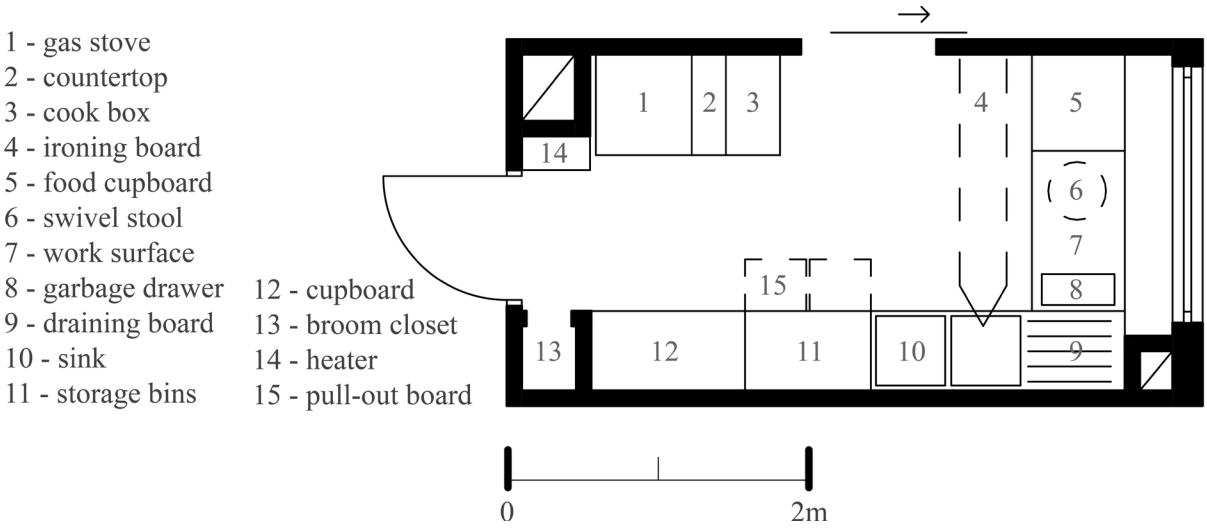

Figure 3 – Frankfurt kitchen designed by Margarete Schütte-Lihotzky, 1926 (adapted from Almqvist, 1940, pp. 28)

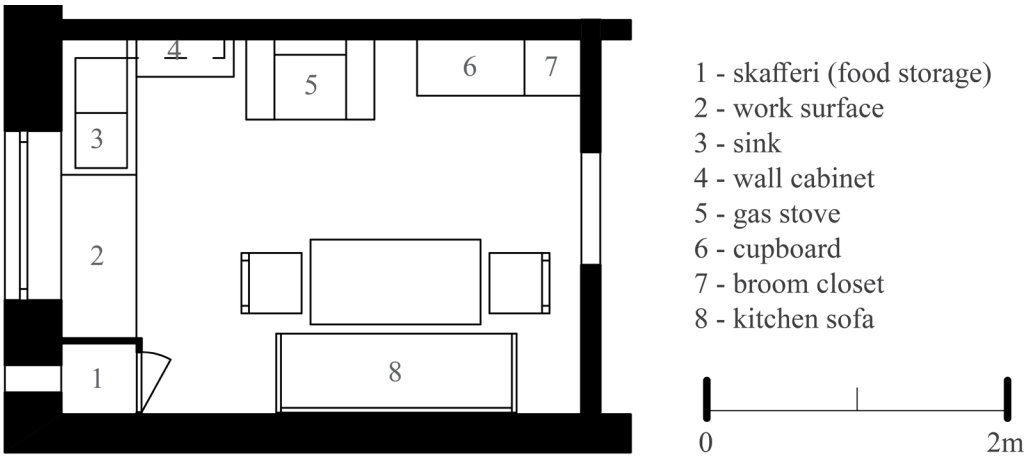

Figure 4 – The Standardization Committee's kitchen design from the exhibition Bygge och Bo, 1924 (adapted from Almqvist, 1940, pp. 148)

Newspapers and magazines distributed information and inspired conversations. In 1927, the Swedish periodical *Husmodern* (1917-1988) published a book about the kitchen and its furnishings in which they presented the modern functionalist laboratory kitchen and contrasted it with the big kitchens of bourgeois apartments (Lee, 2018). The magazine originally intended to help women run a household during the crisis of WWI, but later discussed other areas of domestic work, household economy or raising children.

As part of his work within Standardiseringskommittén (the Standardization Committee), architect Osvald Almqvist imagined the kitchen as an industrial workplace and designed rational layouts and furnishings (Figure 4), which were

presented in various housing exhibitions during the decade (Krantz, 1985; Movilla Vega & Hallemar, 2017). His twelve years of work was summarised in the report *Köket och ekonomiavdelningen I mindre bostadslägenheter* (The kitchen and financing in smaller residential apartments) published in 1934.

WWII brought inventions within the food industry. Conserves, industrial production, and semi-processed food changed what was considered rational housekeeping. Women were seen as the rational workers in the kitchen and several campaigns for women's right to a career were held (Lee, 2018). The societal difference between working-class and middle-class was still significant, not only in terms of women's status, but also in accessibility to infrastructure such as electricity, gas or running water in homes.

During the 1920s-30s, newly built apartments were very functional and equipped with a minimal kitchen, often including a pantry called "skafferi" (Thörn, 2018) (Figure 5). This was a small, separate cupboard with ventilation to the outdoors to keep groceries cool. Up until the 1950s, this pantry was an important part of the kitchen. Another typical kitchen design was the "gärdeskök" (Snidare, 2004). In this layout, the dining room was separate from the kitchen to avoid people sleeping there. (Figure 6). Sleeping in the kitchen was a habit of the poor and considered unhygienic.

In 1936, Hyresgästernas Sparkasse- och Byggnadsförening (HSB), in collaboration with Föreningen Rationell Hushållning (the Rational Housekeeping Association), produced drawings for standardised, rational kitchens, which were later sold to building projects around Sweden (Lee, 2018; Thörn, 1994). HSB has been working with apartment typologies for mass production since its foundation in 1923. Some examples for HSB apartment types can be seen in Figure 7.

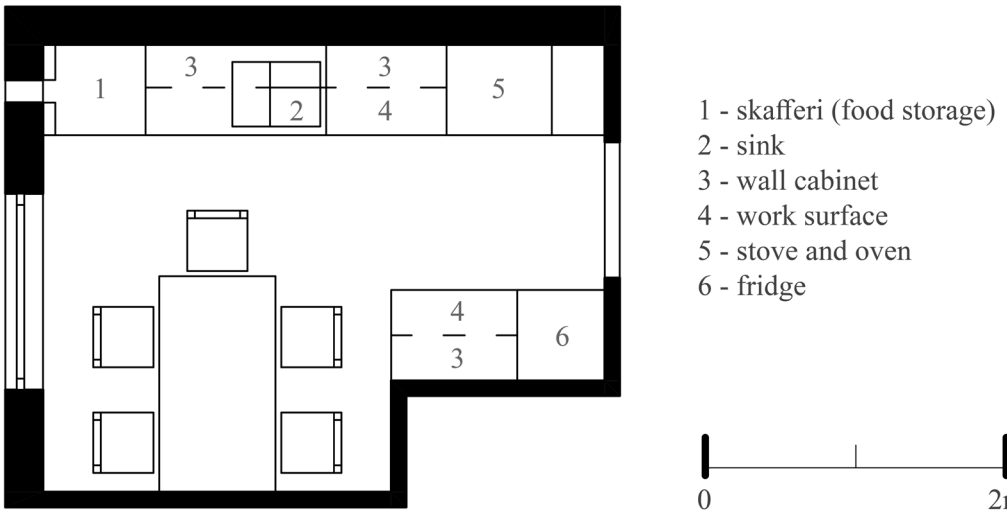

Figure 5 – A kitchen floorplan with a "skafferi" (adapted from Berg et al., 1954, pp. 86)

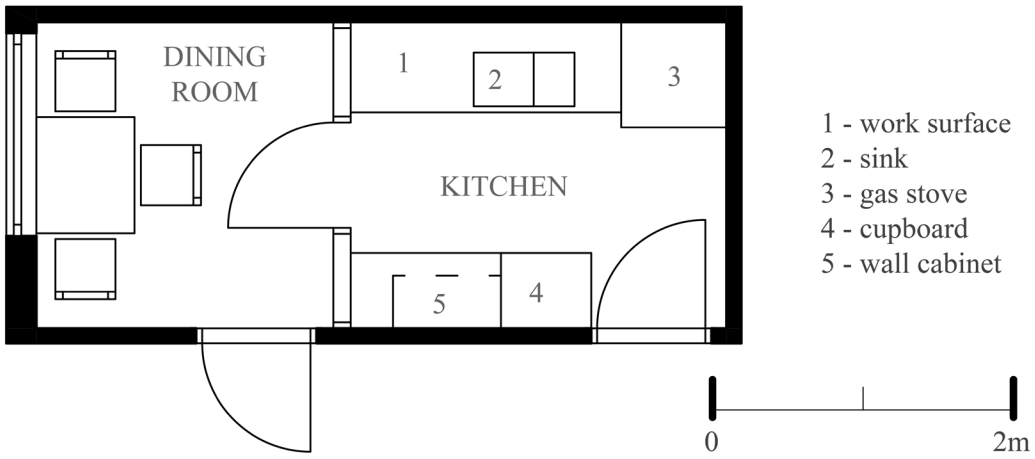

Figure 6 – "Gärdeskök" kitchen and connected dining room (adapted from Nylander, 2018, pp. 108)

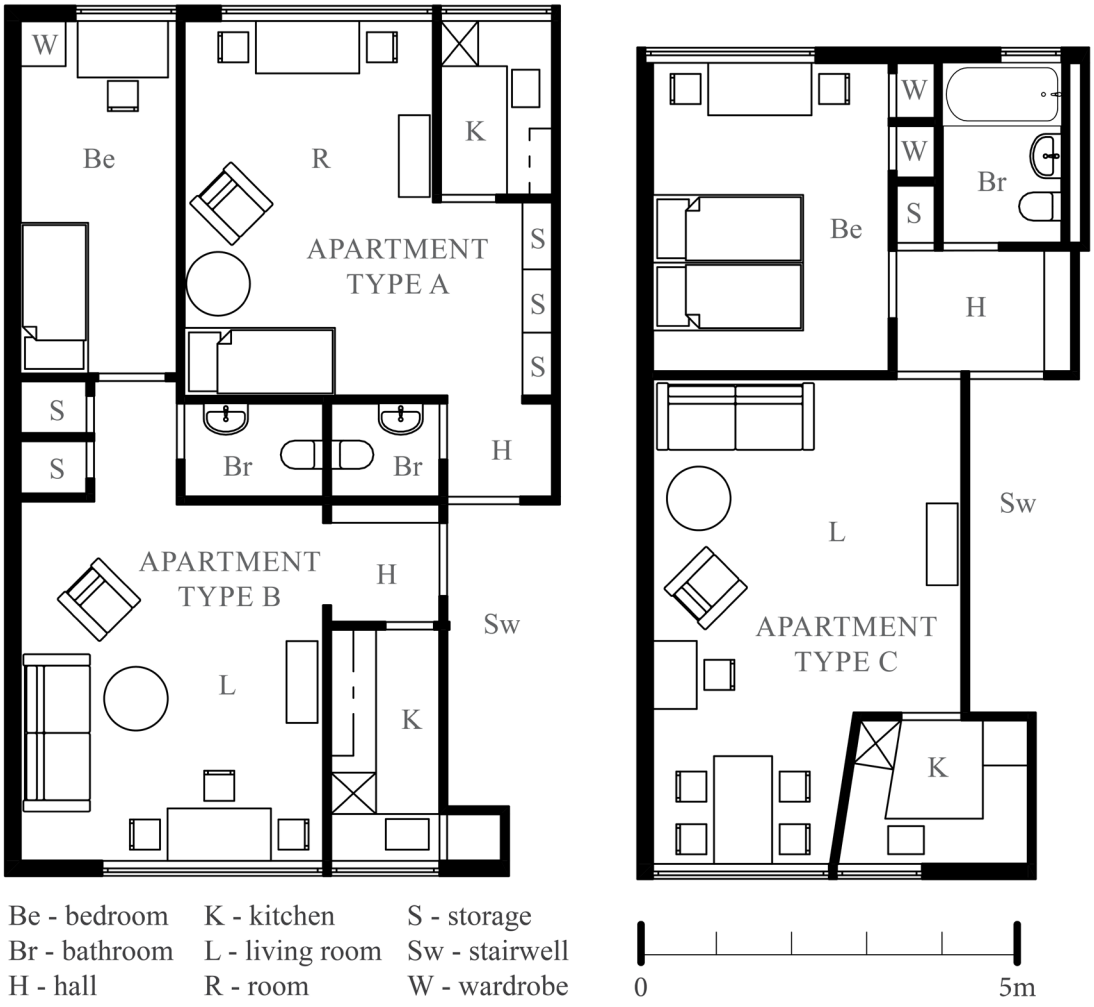

Figure 7 – Examples of HSB apartment types from Gothenburg, 1929 (adapted from Nylander, 2018, pp. 68)

One of the biggest events of the 1940s was the foundation of Hemmens forskningsinstitut (HFI - the Home Research Institute) in 1944. This organisation designed several pieces of research investigating how different household chores were carried out or what would have been the optimal cupboard size, benchtop height and kitchen typologies (Krantz, 1985). The researchers conducted various time studies in a laboratory kitchen, observed housewives carrying out different tasks and considered the anatomical characteristics of women as the main users of the kitchen (Göransdotter & Redström, 2018). The rigorous and systematic work of HFI laid out the grounds of user-centred design methodologies in Sweden (Göransdotter & Redström, 2018). Their work resulted in an extensive description of the ideal kitchen design (including heights and widths of built-in furniture, ideal number of cupboards, placement of major appliances and necessary storage space). Their results were published in the form of reports and books and were used to compile the first building standard (Lee, 2018). Examples of kitchen layouts for different number of users are shown in Figure 8.

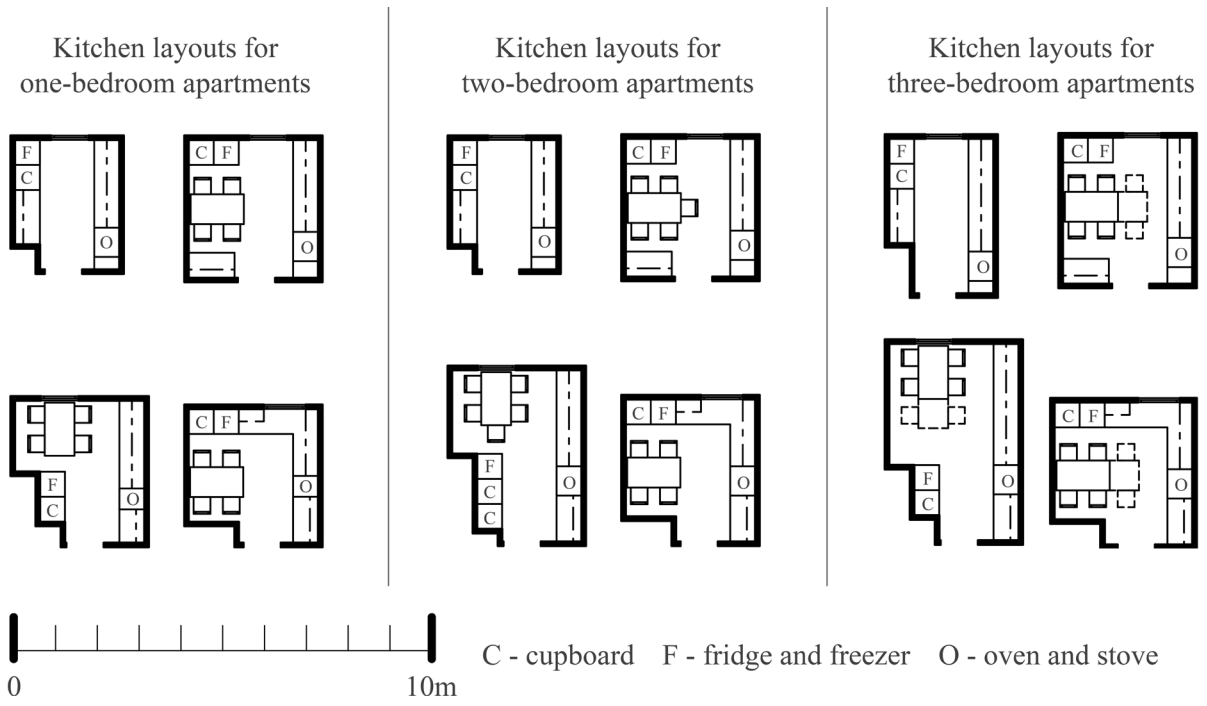

Figure 8 – Kitchen layout recommendations based on the number of bedrooms in the apartments, 1940's (adapted from Movilla Vega & Hallemar, 2017, pp. 245)

Parallel to the work of HFI, furniture designer Lena Larsson surveyed 200 homes, focusing on their living room and kitchen furniture (Snidare, 2004). She pointed out that the living room was still functioning as a "nice room" and that everyday activities were crammed into the kitchen. She also stated that this crowdedness was imposed by big, heavy furniture, which in her opinion should have been replaced with light, modern pieces.

New appliances appeared in the kitchen such as fridges, freezers and electric stoves (Lee, 2018). Frozen meals and processed and packaged foods were more widely available. Despite all these technological advances, the 1945 national housing inventory showed that only 33% had an electric or gas stove and 11% had a fridge (National Board of Housing Building and Planning, 2007).

Towards the end of the 1940s Radiotjänst (Sweden's TV licensing body), in collaboration with HFI, launched a radio show called *Husmorsskolan*, which discussed topics connected to housework (Bergman, 2018). They invited experts from HFI and housewives to give their perspectives on questions related to modernisation, the rationalisation of kitchens and the scientific approach to it.

1950s

Looking at the technical advances, prefabrication and flat packaging became available on the market thanks to the Cornell-kitchen designed in 1952 (Lee, 2018). Finally, electricity and hot and cold running water systems were widespread in homes and plastics, the invention of the decade, appeared in the kitchen, comprising various forms, shapes and associated functions (Snidare, 2004).

In 1956, the Bostadskollektiva kommitté (the Collective Residential Committee) published its results from the 10-year research they had conducted into how domestic labour might be rationalised (Lee, 2018). They suggested a line of collective solutions which reflected the ideas developed nearer the beginning of the century. National housing exhibitions, such as the H55 in Helsingborg or the International Exhibition (Moscow, 1959) sparked relevant conversations around kitchen standards (Lee, 2018). The famous debate between Nixon and Khrushchev about their views on kitchen functions reached all parts of the Western world.

1960s

Surveys showed that, in the 1960s, the biggest occupational group in Sweden was that of housewives (Lee, 2018). Kitchen research was still a big part of HFI's work. In collaboration with Byggforskningsinstitutet (the Building Research Institute) led by Lenart Holm, an inventory was taken, focusing on different kitchen typologies (Krantz, 1985). This became a basis for a new standard published in 1967 (SBN 67). The regulations defined the minimum living space for two people as a minimum of one bedroom, one living room and one kitchen (Nylander, 2013). The standardised kitchen spread all around Sweden thanks to the Miljonprogrammet (the Million Programme), a government initiative aiming to build a million homes in 10 years (1965-74) to tackle the country's housing shortage (National Board of Housing Building and Planning, 2007). Figure 9 shows an apartment floorplan built as part of the Million Program.

Even though IKEA was established in 1943, it didn't produce any kitchen furniture until 1968. In its first years, IKEA disregarded the recommendations for standard measurements, which were based on kitchen research produced by HFI (Husz & Carlsson, 2018). It faced strong criticism from the research community and complaints from end-users. In 1974, it started a collaboration with

Konsumentsinstitutet (the National Institute for Consumer Affairs, formerly HFI) and adjusted their products to the recommended measurements.

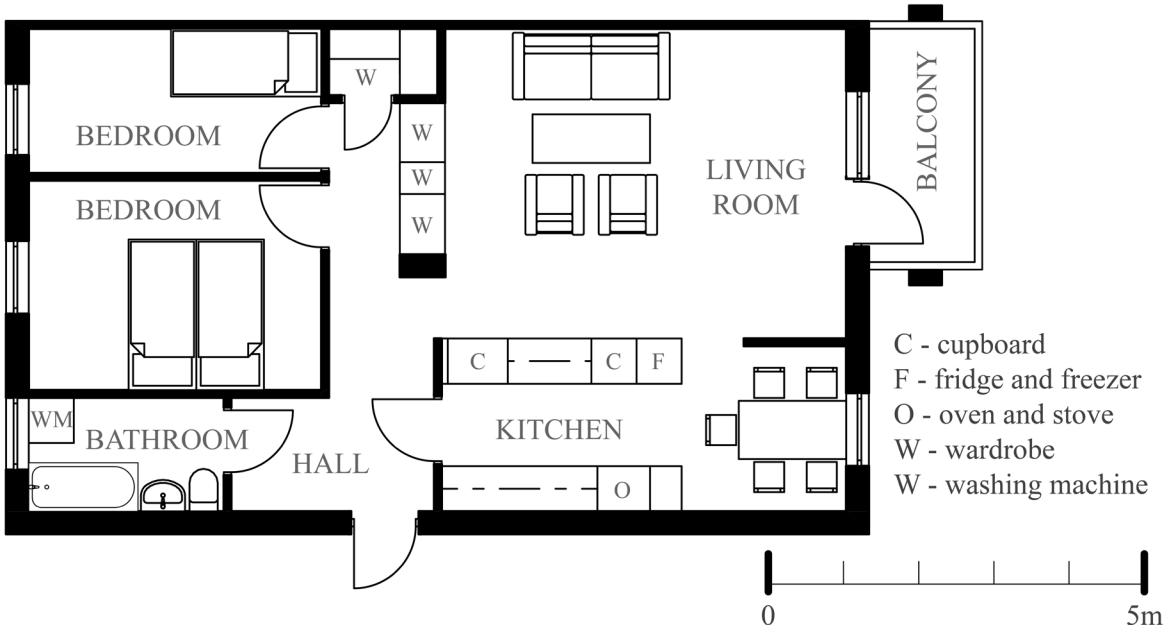

Figure 9 – Apartment type 72, a 72,6 m^2 dwelling from the Miljonprogrammet era. It adopts Ohlsson & Skarne's System 66: an adaptable, module-based construction technique enabling mass production and flexible use. (adapted from Movilla Vega & Hallemar, 2017, pp. 193)

1970s

During the 1970s, men started to take more responsibility in the kitchen and the kitchen was no longer solely the woman's domain (Willén, 2012). To respond to this trend, Alice Thiberg led research into how the kitchen performed when more than one person was using the space. The results were published in two books: *Kök – planering, inredning* (Kitchens - planning and interior design) and *Kök med standard* (Kitchens with standards).

A major influencing factor in this era was the spread of television (Nylander, 2013). Advertisements and shows distributed contemporary views and kitchen designs. Furthermore, books published in the UK and Southern Europe played a significant role in the evolution of kitchens and in shaping user demand (Lee, 2018).

The 1970s kitchen was even more heavily decorated and determined by patterns and colours than those of the 1960s (Snidare, 2004). More emphasis was also laid on adjusting layouts and measurements to fit disabled people (Hallberg & Thiberg, 1985). The Handikappforskningen i Göteborg (Disability Research in Gothenburg) published its results in a form of the report *Kök för rörelsehindrade* (Kitchens for Disabled People).

1980s

As early as the 1980s, cooking became a hobby for men (Lee, 2018) and a new outlook on restaurant culture defined social life and kitchen design for the decade. The kitchen for this postmodern era focused on surface finishings and individualisation (Lee, 2018). Bread machines, ice cream machines and

microwave ovens became everyday items. Open kitchens connected to the living room and kitchen islands (Figure 10) became more and more typical in new buildings (Willén, 2012).

In 1986, experimental residential projects were built with lower standards (Nylander, 2013). The aim was to reduce the cost of building multiresidential buildings. These test apartments had smaller rooms than the regulations recommended, and their kitchens had no daylight. (Figure 11). The proposal received a negative response and never reached mass production.

Husz and Carlsson (Husz & Carlsson, 2018) discuss how the notion of consumer engineering and social engineering were used as tools by kitchen furniture companies to boost their sales. These concepts had been born in 1930s' America. The main idea was to create consumer demand by looking at consumer phycology and behaviour patterns and then using suitable marketing strategies to encourage people to purchase the most recent products. For example, in order to market their furniture worldwide, IKEA advertised their products with the narrative of "Swedishness", communicating a desirable image of the well-known Nordic welfare state.

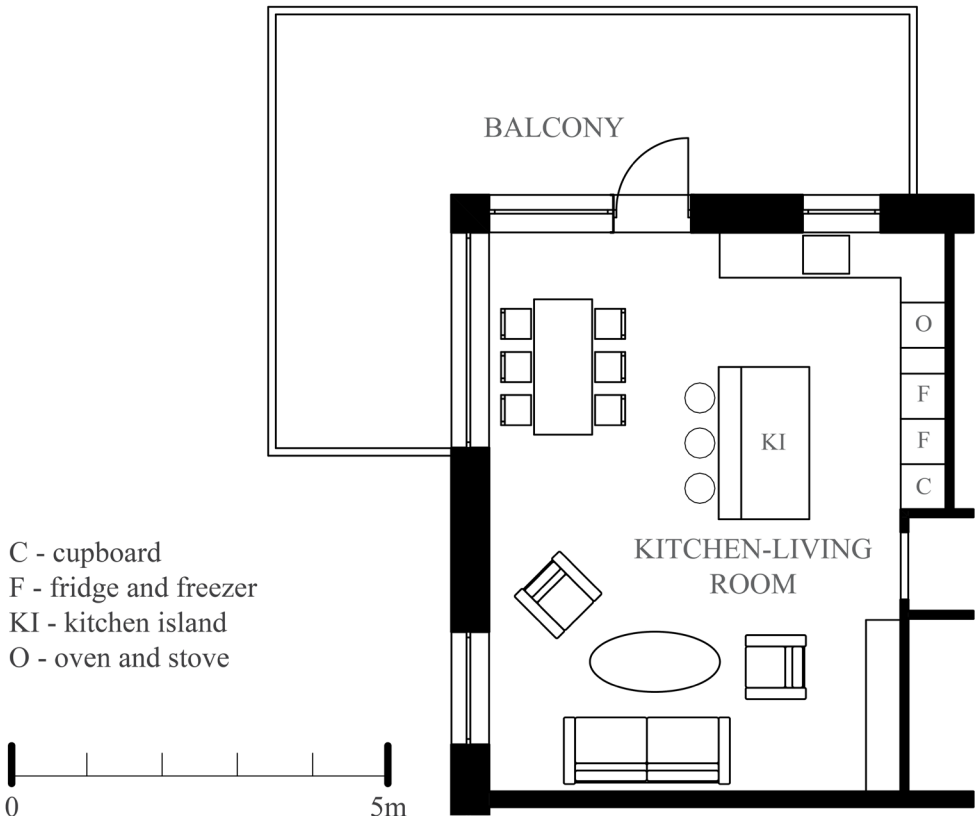

Figure 10 – Combined kitchen-living room example with kitchen island

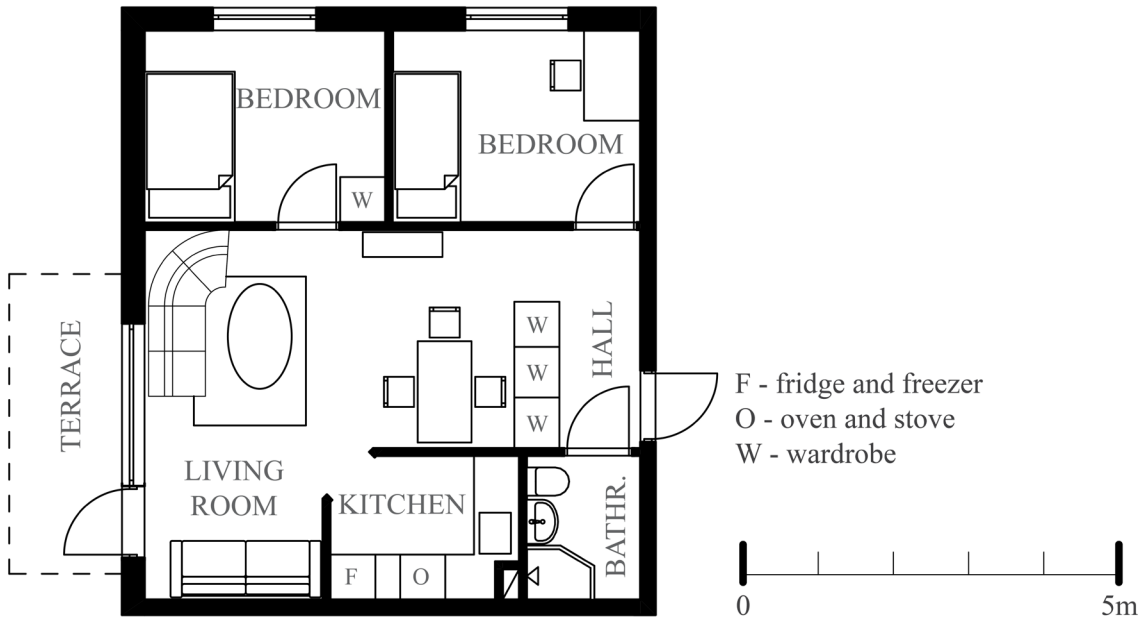

Figure 11 – An experimental apartment floorplan, where standards were consciously neglected to create a compact and economically feasible dwelling. The result included a kitchen without windows, two small bedrooms and a crowded living room. (adapted from Nylander, 2018, pp. 282)

1990s

Although today's building regulations still stipulate strict requirements on housing design (National Board of Housing Building and Planning, 2020), these requirements were somewhat relaxed from the 1990s and onwards (Nylander, 2007). When Sweden joined the European Union (EU), the building standards and regulations were further adjusted to EU building laws. The government took its hands off the building sector and the industry was deregulated (Thiberg, 2007).

A new phenomenon was observable in the 1990s and 2000s. The kitchen became the centre of lifestyle and identity and companies sold their kitchen furniture as lifestyle products, fulfilling not only needs but wishes and dreams (Willén, 2018). As an example, IKEA presents its kitchens as playful, aesthetic, and practical products.

The influence in this period comes from TV programmes, cooking shows, blogs and books (Lee, 2018). Furthermore, exhibitions such as H99, Bo01 and Bo02 spread innovations and new trends. Stainless steel appliances and the induction stove are one of many new inventions.

2000s

During the 2000s, environmental questions became more urgent. For example, the government pushed for more waste-sorting options (Nylander, 2013). In homes, waste-sorting generally takes place in the kitchen. However, in a society where waste is an increasing problem, the kitchen furniture design did not follow up on the need for space in which recyclable rubbish could be stored until it was taken to the recycling station (Sjöstrand, 2018).

Although the literature provided detailed information on the earlier part of the 20th Century, it gave a less comprehensive picture of more recent decades. This was partially due to the decreased funding for researching kitchens (Berger, 2007)

and the government's decision to be less involved in directing the housing market (Thiberg, 2007). Some research continued to investigate contemporary phenomena connected to the kitchen. For instance, Willén's (2012) studies on the open floorplan design in dwellings, or the research into kitchen renovations (Femenías & Geromel, 2019) and connected environmental impacts (Femenías et al., 2018), continued the long tradition of kitchen research in Sweden. However, there is a renewed need for more extensive and comprehensive investigations since new sustainability and circularity demands set new challenges for housing design.

2.2. Narrowing the research focus

The study of the historical evolution of the Swedish kitchen has helped narrow the focus of the research presented in this thesis. It supported the identification of factors influencing the evolution of kitchen design and the evaluation of recently emerged gaps in contemporary kitchen development. In the first half of the 20th Century, kitchen design was strongly influenced by four factors: (1) lifestyles and societal changes, (2) technological advances, (3) kitchen research and (4) governmental regulations. The governmental regulations went hand-in-hand with kitchen research investigating lifestyles, social changes, and technological advances. Extensive research was carried out, from the 1940s to the late 1970s. Its tests and observations produced reliable results which informed regulations and building laws.

After this research era, the investigation stopped and changing demands were not followed up. At the end of the 1980s, the industry replaced the role of the research institutes and a dominant factor in shaping the kitchen design became product development by furniture producers, based on technological advances and changes in lifestyles and society. There is currently a lack of research investigating lifestyles, social changes and technological advances connected to kitchens, which could then inform government regulations. Thus, research is disconnected from the development of informing governmental regulations regarding kitchen design (Figure 12).

At the beginning of the 20th Century, the main motivations for initiating research into housing and kitchens were: a wish to emancipate women, a lack of domestic help, a rising demand for accommodation in urban areas and low-quality dwellings leading to health and hygiene issues. Today, fresh research is needed to tackle environmental issues, as sustainability and circularity agendas are setting new requirements for the built environment.

Based on the historical overview, several research gaps may be identified in current kitchen research, such as spatial design, furniture and appliance design, energy and resource use and waste management. As described in Section 1.1, there is a lack of investigation into spatial configurations regarding the kitchen. Therefore, the focus of this research is investigating the role of spatial configurations in the kitchen context.

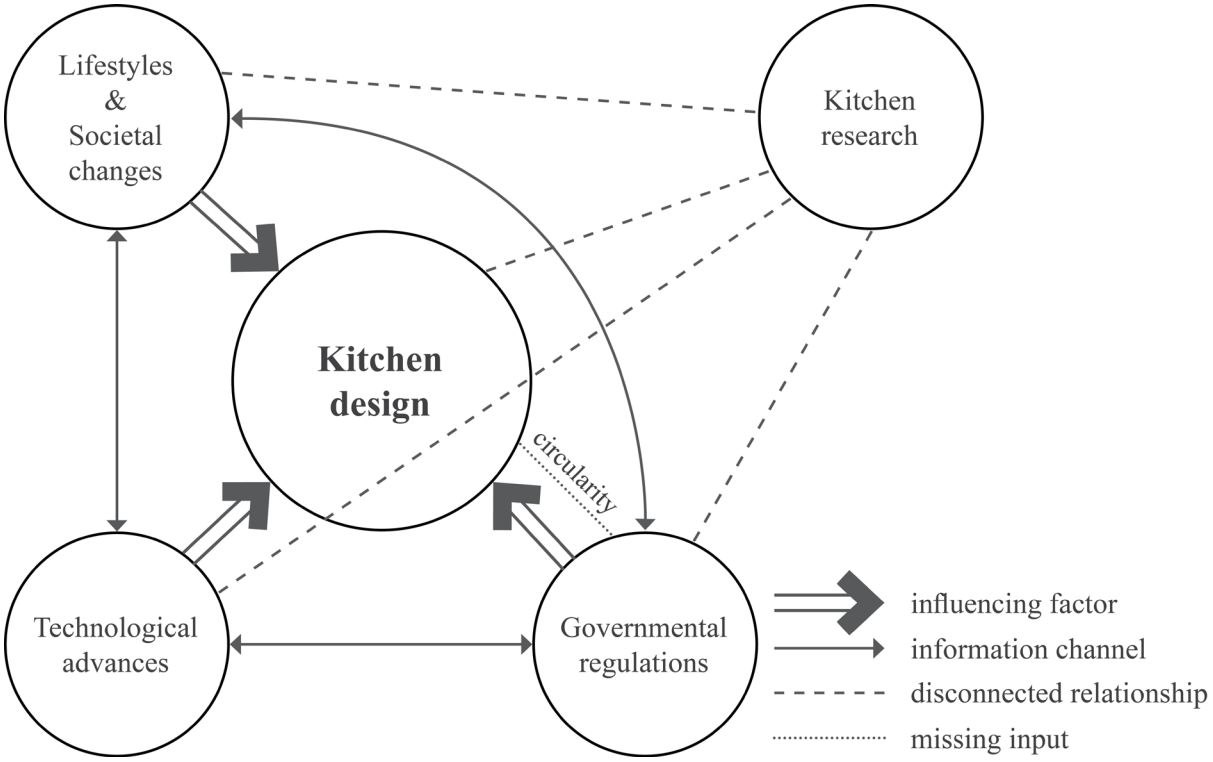

Figure 12 – The influencing factors and their relationships with kitchen design in contemporary situation in Sweden

3. Circular economy, housing adaptability and spatial design

Within the vast field of architecture, the focus of this thesis has been narrowed down to housing design and, more specifically, the kitchen. Furthermore, this work examines the spatial design of the kitchen from a circularity and adaptability perspective. Consequently, the research may be positioned at the intersection of three research areas: CE, housing adaptability and spatial design (Figure 13). The following sections explain relevant theories, concepts and previous research connected to the three research areas.

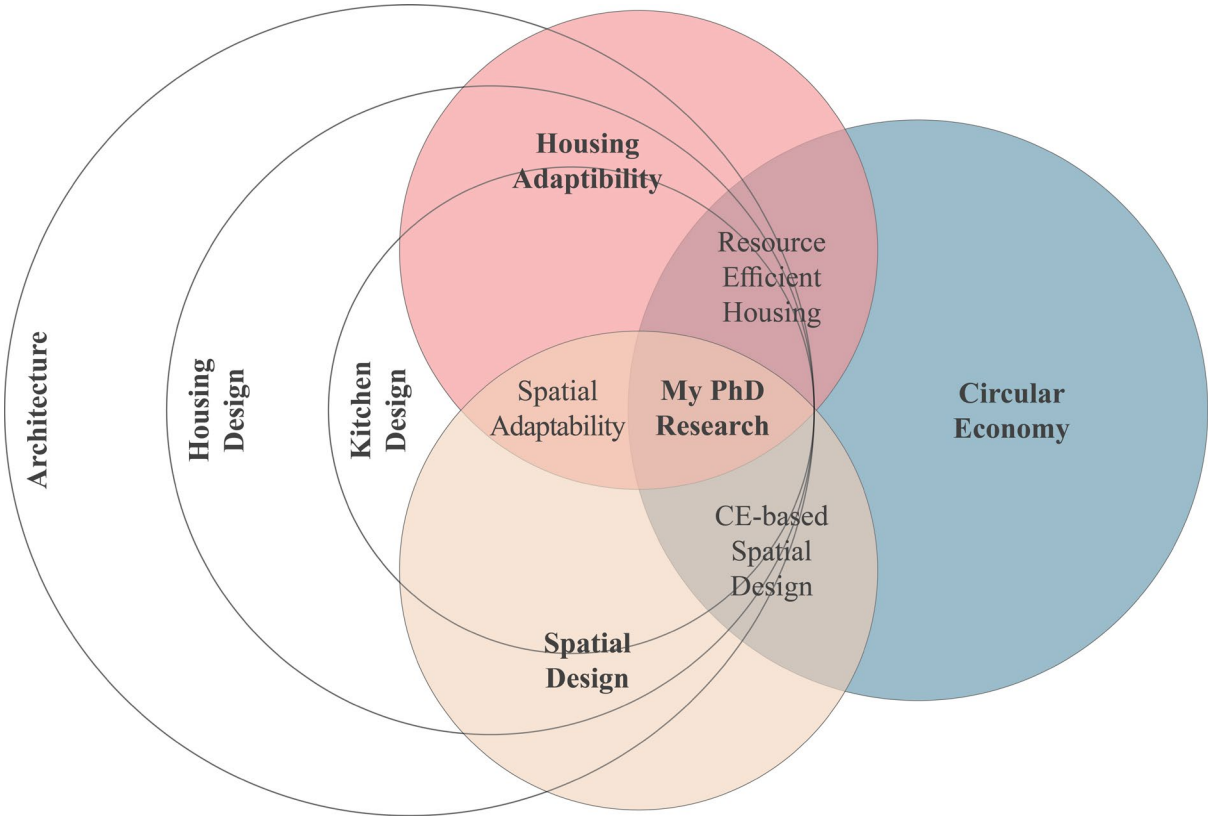

Figure 13 – Positioning the PhD research within the three connected research areas

3.1. Circular economy

The CE is seen as a concept that contributes to achieving sustainability and a growing body of research is examining this phenomenon (Merli et al., 2018). Much of this research stems from the work of the EMF (2013) which laid out the core principles of a restorative CE: a set of re-introducing loops for technical and biological materials. Furthermore, the EMF's ReSOLVE framework (2015) outlines a number of guidelines (regenerate, share, optimise, loop, virtualise and exchange) to assist organisations in their transition to CE. However, there is still a lack of consensus and transparency on the definition of CE (Kirchherr et al.,

2017). To address this issue, Kirchherr et al. (2017) reviewed 114 definitions and then formulated a comprehensive description. In this thesis, CE is embraced as:

> *...an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes [...] with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.*
>
> (Kirchherr et al., 2017, pp. 224-225)

3.1.1. Circular economy in the built environment

Although interest regarding CE in the built environment has increased, there is still only a limited number of investigations in connection with CE in the built environment and applications of circular products or processes are scarce (Minunno et al., 2018; Ness & Xing, 2017). This is due to a lack of common or standardised tools for implementing CE in the building industry and the numerous different interpretations of what CE means in a building context (Rahla et al., 2019).

Leising et al. (2018) aimed to bring clarity to the vast number of interpretations. They state that the CE approach "optimizes the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building" (Leising et al., 2018, pp. 977). Additionally, Pomponi and Moncaster (2017, pp. 771) define the concept of a circular building as "a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles".

Adapting the CE diagram of the EMF, Cheshire (2016) defines five principles for the built environment: building in layers, designing out waste, design for adaptability, design for disassembly and selecting appropriate materials and products. Additionally, many approaches and strategies have been investigated for their potential to support a CE transition in the built environment. Material and resource recovery has environmental, economic and social benefits (Heisel, Schlesier, & Hebel, 2019; Nußholz et al., 2020), lifecycle-analysis-based tools enhance life extension possibilities (Hossain & Ng, 2018) and design strategies such as Design for X (Moreno et al., 2016) or the various strategies of the circular building component generator (van Stijn & Gruis, 2019) support design processes for creating circular buildings, products and services.

The adaptation of these approaches and strategies is obstructed by multiple factors. Building on the work of Kirchherr et al. (2018), Hart et al. (2019) explored barriers to CE within the built environment. They found that cultural barriers (such as "hesitant company culture", "lack of consumer awareness and interest" and "operating in a linear system"), plus market barriers (such as "low

virgin material prices" and "high upfront investment costs") are the most pressing obstacles. Minunno et al. (2018) describes how complex monolithic structures that are hard to physically separate and the prioritisation of demolition over deconstruction are hindering the transition to CE in the built environment. According to their work, these hindrances might be mended through increased modularity and standardisation, design for disassembly and designing mechanical connections over chemical ones, to enable easy separability of building components.

These approaches and strategies outline the development of CE for the built environment. However, the frameworks and design guidelines remain general, seldom address the circular design of specific building functions, and need further proof of testing to overcome the multitude of barriers faced by the building industry. There is a need to advance into the next phase of transitioning towards CE and develop specific circular designs directly for individual building functions. An important step within this next phase is to evaluate current value propositions connected to individual building functions and identify aspects in need of improvement. To do this, value creation and value mapping are important concepts to consider and use.

3.1.2. Value creation in a circular economy

A key element of business models and strategies is value, which is the foundation of Richardson's (2008) business model framework. At the core of his framework stands the value creation logic which consists of three major elements: the value proposition, the value creation and delivery system and the value capture (Richardson, 2008). Nußholz (2017) formulated three questions connected to the three value elements (based on Richardson (2008) and Osterwalder (2010)):

- value proposition – "what value is provided and to whom?"
- value creation and delivery - "how is value provided?"
- value capture – "how does the company make profit and capture other forms of value?".

According to Den Ouden (2012, pp. 117), "[v]alue propositions are those multifaceted bundles of product, service, price, communication and interaction that customers experience in relation to the supplier." The value proposition is a crucial part of the value creation logic, which needs to be carefully defined before value creation and delivery systems and value capture strategies may be developed.

A flaw of conventional business models is the major focus on economic gains and the lack of consideration of environmental and social values (Evans et al., 2017; Upward and Jones, 2016). There is a need to rethink such business models, and incorporate all three pillars of sustainability into value propositions (Bocken et al., 2013; Evans et al., 2017; Kristensen and Remmen, 2019).

With the help of the value mapping tool (VMT) (Bocken et al., 2013), organisations might develop value propositions which consider economic, environmental and social issues. The tool is based on a multi-stakeholder, network-centric approach which supports stakeholders in assessing their value proposition and developing an action plan for shifting their business model towards a more sustainable and circular one (Bocken et al., 2013). By applying the tool, different parts of the value proposition may be organised into three categories: value captured, value missed destroyed or wasted and value opportunities. These categories are further subdivided based on stakeholder segments (customers, network actors, society, and environment). This tool identifies both negative and positive value propositions and gives the opportunity to recognise possibilities for improvement. The VMT also has potential to be applied as an evaluation and screening tool for qualitative material (Bocken et al., 2015).

3.2. Housing adaptability

Adaptability as a concept has a long history dating back to the 1920s. The three main drivers guiding the development of adaptable housing were: the need for a large number of new, efficient apartments in the 1920s, the technological development of construction methods and prefabrication as a tool for mass-producing residential buildings in the 1930s and enabling user participation in the 1960s (Schneider & Till, 2007 as cited in Braide, 2019).

Today, adaptability is recognised as an important aspect of achieving a circular built environment (Cheshire, 2016). According to Geldermans (2016), there is a need for flexible, open design solutions for buildings. He sees adaptability as a tool offering customisation opportunities and advocates a certain level of standardisation while respecting the design integrity of architects. To enable maximum utilisation, buildings must be able to progress in the face of ever-changing demands (Geraedts et al., 2017; Hallberg & Thiberg, 1985). However, previous research has concluded that current apartment designs do not provide spatial diversity to accommodate various households and room sizes and that room organisations mostly favour the needs of a few household types (Braide, 2019; West & Emmitt, 2004). To address this issue, adaptability provides design strategies to increase the spatial capacity and layout variation of dwellings without increasing the size of the apartments or connected production costs (Braide, 2019; West & Emmitt, 2004). Hence, it is favourable to further investigate the potential that adaptability can provide to CE in residential design.

3.2.1. Adaptability in relation to CE

Heidrich et al. (2017, pp. 287) described adaptability as “the inherent properties in a building that gives [sic] it the ability to change, or the relative ease with which it can be changed”. Recently, a growing body of research has investigated

adaptable building designs in the context of sustainability and circularity(Conejos et al., 2013; Gosling et al., 2013; Kendall, 1999; Langston, 2012).

Adaptable design allows economic costs to be minimised since the inherent ability of a building to adapt to changing demands would reduce the cost of extensive reconstruction (Pinder et al., 2013; Slaughter, 2001). Adaptability ensures extended lifespan for buildings and building components and optimised use of built-in resources (Geldermans et al., 2019a). Furthermore, it prevents premature obsolescence, unnecessary reconstruction, and redundant material flows (Kendall, 1999; Slaughter, 2001), which would reduce the environmental impact of the building industry. From a social sustainability perspective, adaptability has many benefits, for instance, reduced number of relocations (Baum & Hassan, 1999; Plaut & Plaut, 2010) or user control and empowerment (Braide, 2019; Till & Schneider, 2005). These advantages are interrelated and simultaneously stimulate each other. For instance, with higher user satisfaction the number of relocations can be reduced, and premature alterations might be avoided, which in turn might diminish material flows and economic costs.

By adapting the EMF's CE diagram, design principles for the built environment have been defined (Cheshire, 2016), one of them being design for adaptability. Strategies such as flexibility of floorplans (Langston and Shen, 2007), disassembly options (Conejos et al., 2013), modularity and standardisation (Geldermans, 2016; Geraedts, 2016), or over-capacity (Gosling et al., 2013) may support architects in enabling adaptable building designs. However, these strategies are seldom applied in practice. This may be attributed to their perceived affiliation with increased up-front investment and uncertain economic benefits (Fawcett, 2011; Pinder et al., 2013). For instance, over-capacity requires extra floor area which, in turn, increases initial costs. This is not in the interests of housing developers, as their aim is to provide the regulatory minimum required for housing designs and keep their costs to a minimum and profits to a maximum (Heidrich et al., 2017). Furthermore, adaptability frameworks and models fall short on supporting the design of physical or context features and there is a need to validate the propositions of the aforementioned frameworks and models (Rockow et al., 2019).

Research into adaptability investigated issues in connection with housing design. These studies focused on understanding the ability of dwellings to accommodate changing demands and examined specific aspects connected to adaptability, such as generality and flexibility of rooms (Femenías & Geromel, 2019; Manum, 2005), or size and furnishability of dwellings (West & Emmitt, 2004). However, there is a dearth of studies on how to create adaptable designs for certain building functions in connection with a CE in residential buildings.

3.2.2. Adaptive capacity

While adaptability is a value created through design solutions (Geraedts et al., 2017) adaptive capacity is a metric for measuring a building's ability "[…] to cope with future changes with minimum demolition, cost and waste and with maximum robustness, mutability and efficiency" (Sinclair et al., 2012, pp. 40). Geraedts et al. (2014) formulated adaptive capacity indicators which focus on the building scale. These indicators assess buildings' or building units' ability to enable major and minor changes in the finishings, spatial configurations, layout, room organisation, infrastructure, or structural components. Their definitions are detailed in Table 3.

Table 3 - Overview of original definitions of the adaptive capacity indicators

Indicators*	Definitions*
Quality	Changing the layout and finishing (look and feel) of the user unit in a building
Redesign	Changing the layout of the user units in a building and/or changing the functions of the user units in the building
Relation Internal	Changing the internal relation with other users/stakeholders in the building
Grain size	The number of user units in a building (increasing or decreasing)
Facilities	Changing the facilities (infrastructure) in the user units, in the building, and/or at the location level
Reallocate Internal	Changing the location of the user units in a building
Transfer	Whether or not a building can be transferred to another location
Expansion	To what extent the use surface of a user unit in a building should be extendable in the future (horizontal and/or vertical)
Rejection	To what extent the use surface of a user unit in a building should be contractable in the future (horizontal and/or vertical)

* as in Geraedts et al. (2014)

3.2.3. Previous literature on adaptability of dwellings and kitchens

Previous literature examined the adaptability of dwellings and, as part of these investigations, revealed some insights into important aspects connected with kitchens. These studies often used floorplan analysis as an assessment tool. The most relevant findings of this literature are highlighted below, as background to what has been already observed regarding the spatial adaptability of dwellings and kitchens.

Household compositions change over time and this influences their spatial needs (Braide, 2019). To respond to these changing needs, a household might decide to relocate or adjust its current dwelling to the new demands (Braide, 2019). Previous research found that end-users prefer not to relocate when their household demands change; if possible, they adapt their dwelling to their needs through spatial alterations (Braide, 2019; Rossi, 1955). In this sense, adaptable

apartment design becomes a favourable solution for providing for end-user needs and enabling low-impact alterations.

In a large study examining 313 households, Femenias and Geromel (2019) concluded that there are four main drivers of user-driven renovations in apartments: (1) contemporary design of homes, including regulations, (2) a lack of functional and technical quality of materials and components, (3) a wish to personalise and adapt the dwelling as needed and (4) second renovations resulting from other alterations to the dwelling (as structural systems are difficult to physically separate (Brand, 1994)). Furthermore, their study showed that the adaptive capacity of the apartments was influenced by the floor area and organisational structure of the floorplans.

Examining Norwegian apartment floorplans to evaluate room sizes and room organisation over time, Manum (2005) found that combined kitchen-living rooms became a widely used design solution and that the rooms in the dwellings were more specific, enabling only certain functional uses and hindering adaptability. He concluded that contemporary floorplan designs mostly supported one household composition (young families with children) and did not accommodate the needs of other household types.

West & Emmitt (2004) investigated how contemporary needs and lifestyles of households are met by the floorplan design of their homes. They focused on room dimensions and layouts to assess the adequateness of room sizes and furnishability. Their findings revealed that most dwellings were functional only at sub-maximum capacity. There was a lack of space for furniture, circulation, access, and storage. However, they emphasised that a large-sized dwelling was no guarantee of a functional floorplan design; some of the smaller dwellings enabled more functionality through simple design solutions. They also emphasised that "good design does not necessarily demand a large increase in floor area and consequent cost" (West & Emmitt, 2004, pp. 299).

Tervo & Hirvonen (2019) also examined the spatial needs of inhabitants in Finnish studio or one-bedroom apartments. Their results showed that end-users desired larger kitchens and apartments. According to their survey participants, the ideal apartment would consist of two bedrooms and have a floor area of 69m^2.

Within the kitchen context, an interview study examining 20 households found various reasons and drivers that indicated a need for more adaptable housing design. End-users often regard renovation as a necessary task to create a space within which they may thrive (Hagejärd et al., 2020). The reasons behind such renovations are: layout, lack of work surface, small room size, obsolete furniture or appliances, a wish to enhance the appearance of the kitchen or increasing and decreasing households (Hagejärd et al., 2020). Additionally, end-users tend to expand their kitchen when extra space is available (Femenías & Geromel, 2019). This is often done by creating a combined kitchen-living room (Hand et al., 2007; Judson et al., 2014; Maller et al., 2012). Kitchen islands were also a popular complement to built-in furniture during kitchen renovations

(Femenias & Geromel, 2019). Although, these were inserted at the expense of such qualities as minimum requirements for accessibility since there was a lack of free floor area in the original floorplan.

3.3. Spatial design of the kitchen

As described in Chapter 1, spatial design is one important aspect of housing design. Relevant spatial design formulations connected to the kitchen were found in the literature connected with the housing research conducted in the 1900s, and in the Swedish building regulations, which were informed by the outcomes of the aforementioned housing research. Eleven spatial characteristics were identified (Figure 14). More details on the literature and methods used in identifying the spatial characteristics of the kitchen are presented in Section 5.3. The clusters of the spatial characteristics are this thesis' contribution and served as a starting point for developing the spatial analytical framework described in Section 5.3.2.1. The following section presents the identified spatial characteristics, connected design formulations and their relevance for adaptability.

Figure 14 – The eleven spatial characteristics connected to kitchen design

3.3.1. Spatial characteristics of the kitchen

The kitchen's contact with other rooms influences its use. The overall **room organisation** of apartments has changed over time, as it adapted to new demands. In the early 20th Century, floorplans were characterised by general rooms (Brkanić et al., 2018; Manum, 2005; Nylander, 2018). During the middle of the century, the entrance hall became the communicative hub from which most other

rooms could be reached (Nylander, 2018). Towards the end of the 20th Century, the living room took over this role and the kitchen was mostly accessible by passing through this room (Manum, 2005; Thiberg, 2007). With today's surface-compressed housing solutions, the combined kitchen-living room has become standard (Nylander, 2018; Willén, 2012). During these changes, the kitchen's role and function evolved too: from a service zone at the back of the dwelling to the heart of the home, from a separate room to an open space (Brkanić et al., 2018).

Space syntax (Hillier & Hanson, 1984) is commonly used to analyse the spatial organisation of dwellings. In particular, connectivity graphs are a popular tool for describing spatial configurations (Bafna, 2003). These graphs then may be used to measure specific characteristics. Rooms may be categorised based on their connections to other rooms (Hillier, 2007, pp. 250-251): A: "dead-end" room; B: "pass-through" room; C: room in a single ring; or D: room that is part of more than one ring (Figure 15). Internal rings appear when a node may be re-entered through a loop in the graph. These rings may facilitate movement, enable flexible use (Femenías & Geromel, 2019) and increase the feeling of spaciousness (Caldenby et al., 2019). However, rings created by freestanding tall cupboards are less appreciated by end-users (Femenías & Geromel, 2019).

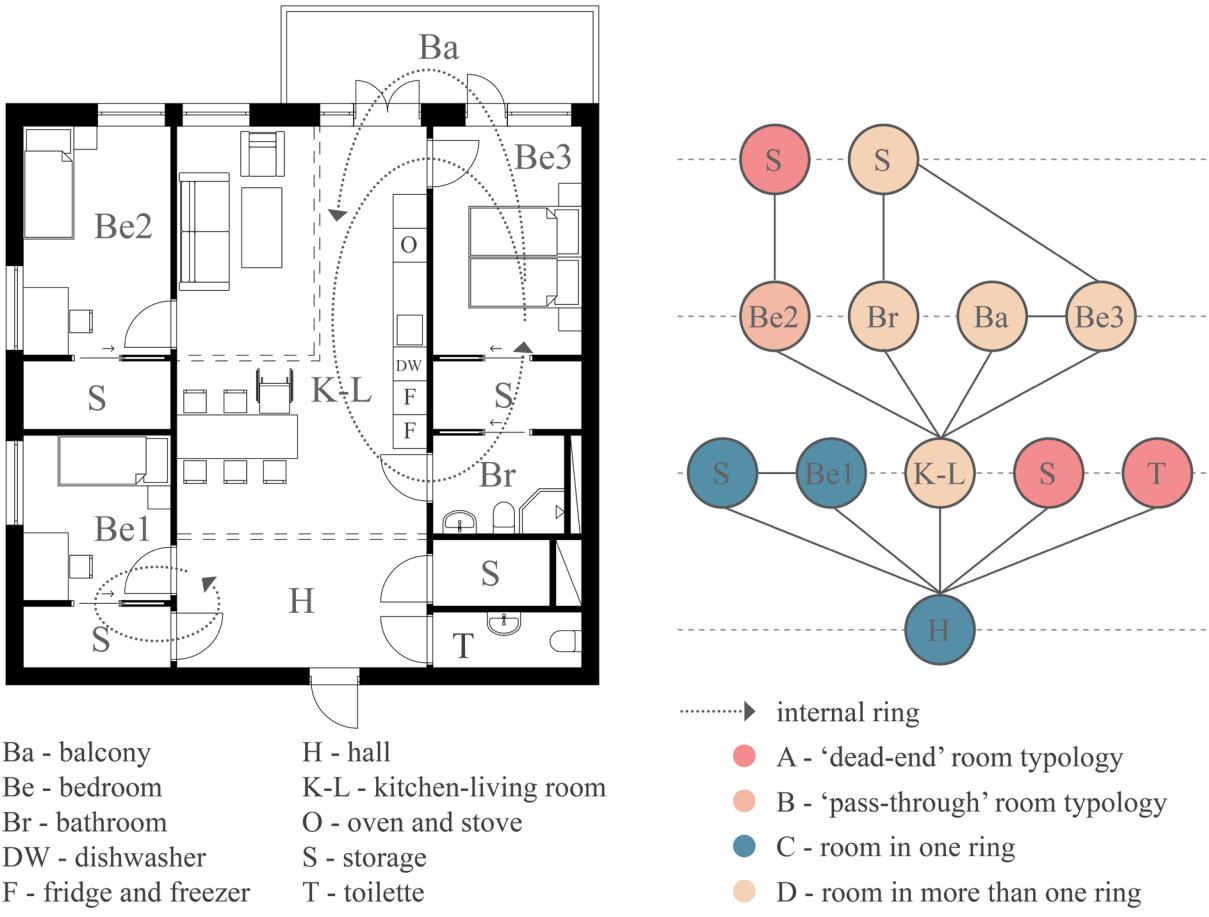

Figure 15 – A floorplan example (left) and its convex map with the typology of each room (right) according to the definitions of Hillier, 2007, pp. 250-251

Combined kitchen-living rooms were created to save floor area (m^2) in apartments (Thiberg, 2007) and to provide a larger room for family gatherings (Nylander, 2018). This design solution creates a feeling of spaciousness and enables social activities (Nowakowski, 2015), which is appreciated by users (Hagejärd et al., 2020). Disadvantages include noise disturbance from cooking activities or visual impact of an untidy kitchen (Thiberg, 2007). Swedish regulations specify that in apartments larger than 55 m^2, the kitchen must be a separable room (National Board of Housing Building and Planning, 2020). This means that, even if an apartment is built with a combined kitchen-living room, it must be possible to divide it into two separate spaces appropriate to their function, with at least one window as source of direct daylight.

Tervo & Hirvonen (2019) surveyed a large number (n = 1,453) of 'solo dweller' households, living in one-room apartments. Their findings show that even though open floorplans were the most popular among respondents (56%), a significant portion (40%) of participants would have preferred a separate kitchen. They further highlight that this contradicts current design practices, as apartments with open floorplans are mostly constructed nowadays.

The size (m^2) of the room is not the only distinct characteristic defining its usability. For instance, the positions and opening directions of **doors** determine the use of the room and how it may be furnished (Thunström, 2011). If these characteristics are not well designed, flexibility for diverse room use is lost.

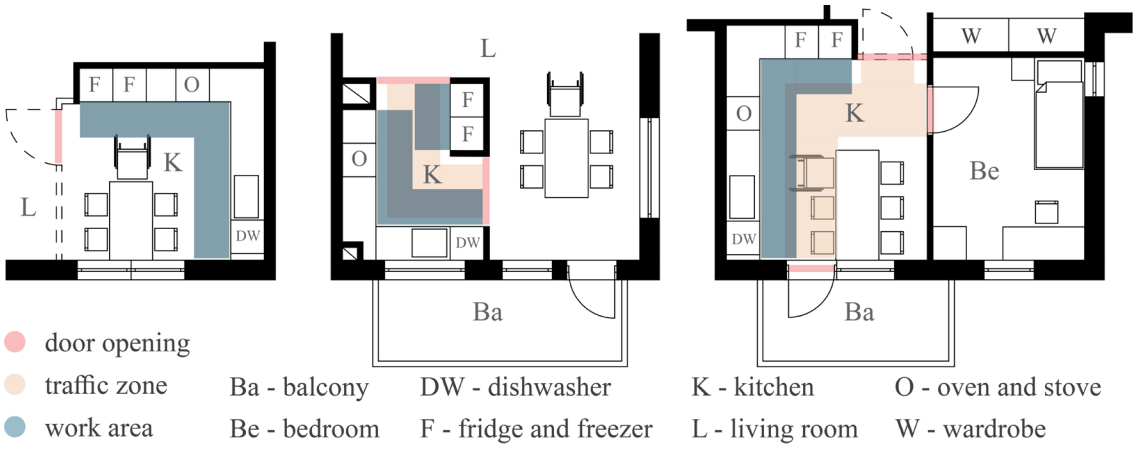

Figure 16 – The relations between door openings, traffic zones and work area in kitchens with one (left), two (middle) and three (right) door openings

Nowakowski (2015) recommends limiting the number of doors connecting the kitchen to other rooms: one connecting to the entrance hall and one connecting to the living room. This is to enable better "furnishability" and restrain traffic zones. An increased number of doors (and hence traffic zones) may limit the amount of built-in kitchen furniture and hinder the use of work areas. Figure 16 demonstrates the relationships between door openings, traffic zones, work areas and furniture in kitchens (from Study 2) with one, two and three door openings

in the space. It can be noted that traffic zones and work areas often overlap and in the kitchen with three door openings the furnishability of the room is compromised. However, from an adaptability perspective, it is more difficult to create new door openings than to restrict the use of existing ones.

The **kitchen typology** is the layout of built-in furniture, influencing the spatial use and experience of the room (Krantz-Jensen, 1963). Based on how built-in furniture is arranged in the kitchen, Krantz-Jensen (1963) defined four main typologies: I-kitchen, L-kitchen, parallel-kitchen and U-kitchen. The I-kitchen, hereinafter referred to as a "straight-kitchen", has its sink, oven and main work surfaces placed along one wall in a linear arrangement. Some tall cupboards (accommodating the fridge, freezer, or storage) may also be placed along another wall. The L-kitchen is an angled furniture, giving greater distances between work units. In a parallel-kitchen, the built-in furniture is placed along two walls facing each other. There must be enough space between the two sides of the furniture (National Board of Housing Building and Planning, 2020) for multiple users to work at the same time and opposite cabinets to be opened comfortably. In a U-kitchen, the two parallel sides of a built-in furniture are connected by an extra bench. In open L- or U-kitchen, the different wings of the built-in furniture are separated by a door opening, thus eliminating the closed corner (Thiberg, 2007). Figure 17 summarises some layout variations of kitchen typologies.

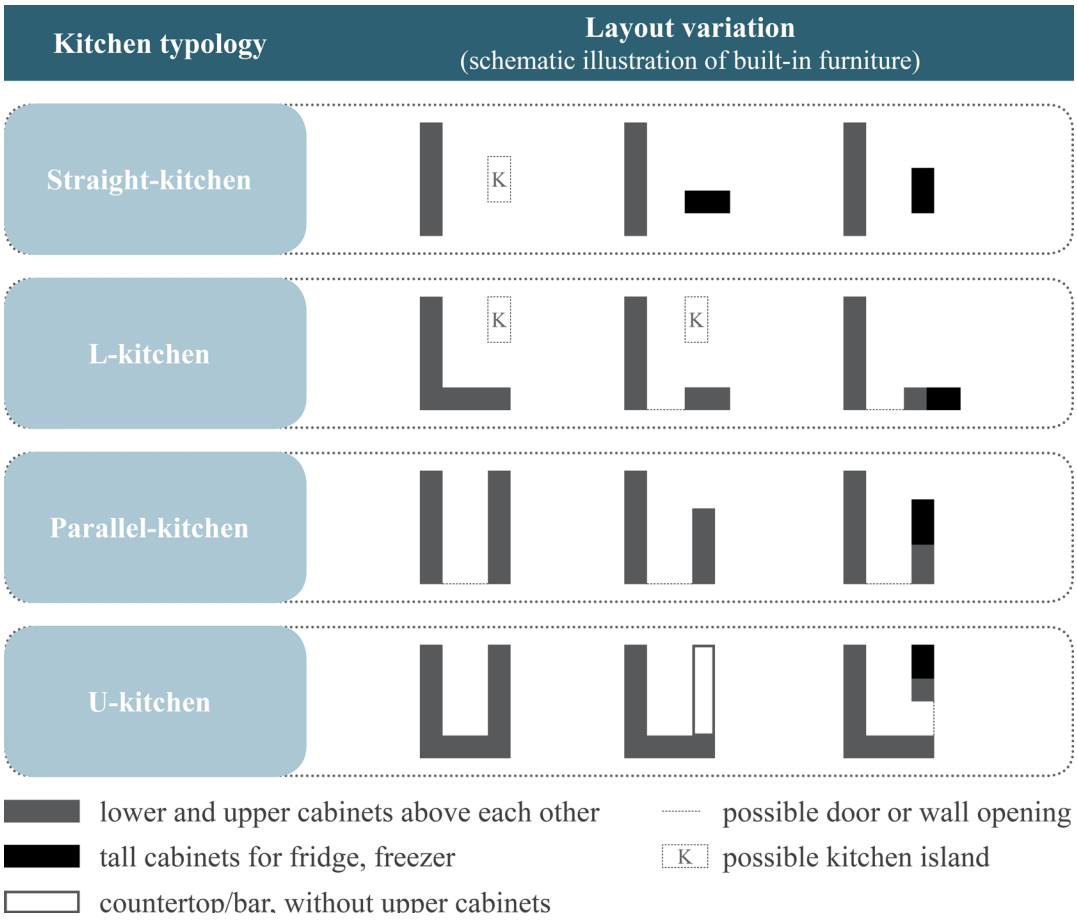

Figure 17 – Layout variations of kitchen typologies

Kitchen islands are most common in larger apartments or open floorplan solutions (Nowakowski, 2015). Besides the added work surface and storage space, kitchen islands might include some appliances (such as stove, mini-fridge, wine cooler) or a sink. Although kitchen islands are popular for end-users, there is often not enough space in the initial floorplan to install one. However, end-users tend to alter the floorplan of the dwelling to find space for it (Femenías & Geromel, 2019; Geromel, 2016). In some cases, these alterations result in loss of some qualities of the floorplans (e.g., minimum requirements for accessibility).

Ambitions to save space and reduce the size of dwellings led to a shrinkage in important measurements (Nylander et al., 2019). In the kitchen, multiple users should be able to work at the same time without the space feeling crowded (Thiberg, 2007). To thrive in one's home, there is a need for free **floor areas** (empty, unfurnished floor surfaces) and "[g]enerous measurements [of spaces, which] increase well-being and convenience and decreases the risk of accidents" (Thiberg, 2007, pp. 16). For accessibility, comfort, and safety reasons, it is important to have adequate free floor areas at work units, around the dining area and in front of doors. Furthermore, generous free floor areas also provide for flexibility, adaptability and temporary remodelling (Hallberg & Thiberg, 1985).

Kitchens in new-build apartments should be fit for use by disabled people or easy to adapt to their needs without major intervention in the dwelling (Örnhall, 2019; Thiberg, 2007). According to Thiberg (2007), generous free floor areas would not only provide for **accessibility** and hence pleasant use of the kitchen for a disabled person in a wheelchair but also for comfortable working space for multiple users carrying out activities at the same time. This would accommodate the needs of various end-user groups, which in turn may contribute to less impact from renovations and retrofits.

The kitchen has three types of **infrastructure** influencing the usability of the space: the electrical outlets, plumbing and ventilation system. To be able to use different kitchen appliances in different locations in the room, electrical outlets must be sufficient in number and positioned at different heights (Thiberg, 2007): For example, behind the lower cabinets (for dishwasher, stove and oven), under the upper cabinet (for smaller appliances used on the countertop), in the upper cabinet (for ventilation hub) and in tall cupboards (for built-in appliances such as fridge, freezer or oven).

Plumbing and ventilation systems usually starkly define the location of the sink, dishwasher, stove, oven, and ventilation hub. To be able to redesign the interior of the kitchen, the position of the piping and exhaust air duct should not lock the position of the connected appliances and sink (Thiberg, 2007). It is important to create design solutions that allow future relocation of plumbing and ventilation system outlets; with, say, water pipes that may be run behind the lower cabinets or space for horizontal air vents in the cabinets under the ceiling (Thiberg, 2007).

The **work-triangle** concept in the kitchen originates from the housing research conducted at the University of Illinois in the 1940s (Ranney, 1949). The concept determines the efficient distances between the three most used workstations: the sink, the stove and the fridge (Figure 18). The aim of the concept is to define the distances between the three workstations to eliminate unnecessary efforts, and to provide enough work surface and distance between them for a comfortable use of the kitchen (Kang & Lee, 2016).

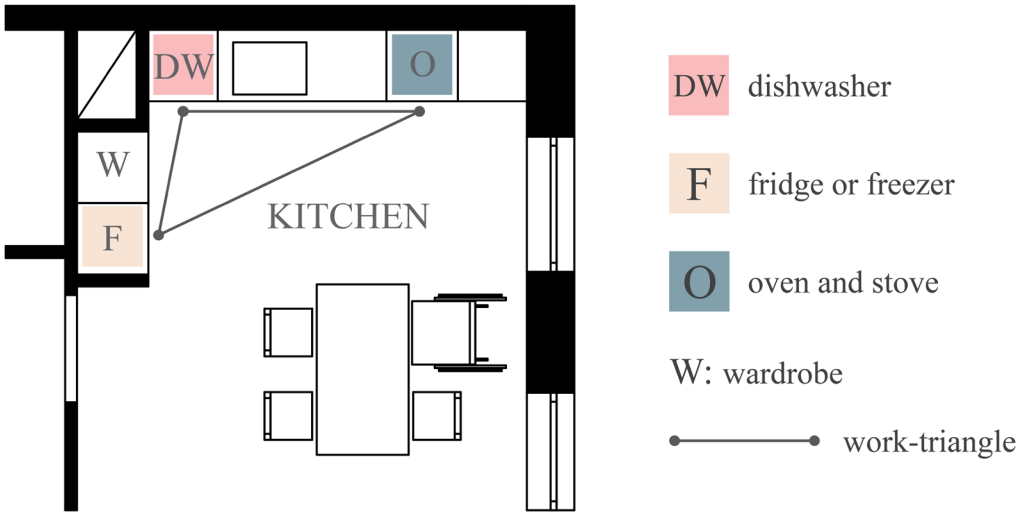

Figure 18 – Illustration of the work-triangle concept

Providing sufficient **daylight and window** surfaces is important for the everyday activities carried out in the kitchen. Daylight coming from the side of work surfaces is preferred (Thiberg, 2007). This must be complemented with electric lighting, especially above work surfaces (such as countertop, table, and stove). Swedish regulations require at least one window in the kitchen to provide enough natural daylight for the whole room, but there is an exception for apartments smaller than 55 m^2 (National Board of Housing Building and Planning, 2020).

The **dining** area plays an important role, both for activities carried out by household members and while hosting guests (Hagejärd et al., 2020; Thiberg, 2007). Therefore, it is favourable to have a spacious dining table, not only for meals but for diverse activities. Furthermore, the dining table may serve as an extension of the countertop of the built-in furniture and should, therefore, be located near the work surfaces and storage spaces. If the dining table is not placed in the kitchen, it must be positioned at convenient proximity (Örnhall, 2019). Additionally, a window or outdoor spaces (balcony or terrace) close to the dining area gives qualities such as direct natural daylight for mealtimes and a view, for enjoying the surroundings (Thiberg, 2007; Willén, 2012).

All the recommended dimensions and positions of the above spatial characteristics influence the spatial design of the kitchen. The examined literature focuses on the functionality of the space and less on creating solutions for

enabling adaptability. How these spatial characteristics are defined might affect the adaptability of the room. Therefore, it is important to investigate which spatial kitchen design might explicitly enable adaptability and hence contribute to circular housing design.

3.4. Summary

This chapter highlighted relevant concepts and previous research in relation to the three research areas within which this thesis is positioned (CE, housing adaptability and spatial design) and focused on an examination of one building function, the kitchen. Firstly, in connection with a CE, it is important to highlight the lack of standardised design solutions that could support a CE transition within the built environment. Secondly, there is a long tradition of research focusing on adaptability, although there is a need to develop circular adaptability strategies in connection with housing design. Thirdly, as spatial design plays a significant role in the field of architecture, it is necessary to investigate it simultaneously from the perspectives of adaptability and circularity. The methods used and developed in Studies 1 and 2 are built on the information presented in this chapter.

4. Theoretical framework

Since the 1990s, there has been rising interest in creating understanding on the interrelationship between objects, connected meanings and human activities. Theoretical frameworks (such as the actor-network theory (ANT) or sociomateriality) have been developed to enable investigating such interrelationship. To be able to study and analyse the complex subject of the kitchen, this thesis adopted the theoretical framework of sociomateriality, which enables the examination of both human and non-human aspects of a certain phenomenon (Orlikowski, 2007). Sociomateriality was used as a framework to set the ontological and epistemological grounds of this thesis and as a reflective approach to discuss the findings presented in Studies 1 and 2. In this Licentiate, the human perspective is mainly represented by stakeholders connected to kitchen production and, to a lesser extent, by end-users. The non-human object of the investigation is defined as the kitchen.

4.1. Sociomateriality

The concept of sociomateriality builds on the work of Latour (2005) and Law (1992) within the field of ANT. ANT and, hence, sociomateriality is mostly used in organisation and management research to understand the relationship between technology and humans (Orlikowski, 2007), but even in architectural research, these theories have proved to be a useful tool in investigating how end-users influence the evolution of physical space (e.g., Acton, 2017; Buser & Carlsson, 2017).

Sociomateriality is a "theoretical perspective" (Orlikowski, 2007) through which researchers may study the entangled nature of social phenomena and materiality (Moura & Bispo, 2020). These two elements of sociomateriality are considered to be interlocked and inseparable parts which mutually influence and shape each other (Leonardi, 2012, 2013; Moura & Bispo, 2020; Orlikowski, 2007). Leonardi (2012, pp. 34) summarised it thus: "materiality is […] created through social processes, […] it is interpreted and used in social contexts and […] all social action is possible because of some materiality." Leonardi (2012, pp. 32) further defined sociomateriality as an "[e]nactment of a particular set of activities that meld materiality with institutions, norms, discourses, and all other phenomena [that are] typically define[d] as social."

Simply put, sociomateriality entails a set of activities which merge social phenomena and materiality (Leonardi, 2012). In this context, materiality refers to the inherent properties of physical and non-physical objects, including material and form. Materiality is the "arrangement of an artifact's physical and/or digital materials into particular forms which endure across differences in place and time and are important to users" (Leonardi, 2012, pp. 42). Social phenomena include, for instance, institutions, norms, discourses, decision-making, strategy formulation (Leonardi, 2012), symbols, meanings, desires, fears or cultural

discourse (Fenwick, 2014). In connection with these two parts of sociomateriality, researchers recognised social agency (coordinated human intentionality) and material agency (ways in which materiality acts) (Leonardi, 2012). These two differ from each other in intent, which is only associated with humans (Latour, 2005). Social phenomena and materiality become entangled in the space of practice which is the arena of multiple activities which shape the sociomaterial reality (Leonardi, 2012; Orlikowski, 2007).

In summary, there are three main characteristics of sociomateriality (Faulkner & Runde, 2012):

(1) Humans and (physical and non-physical) objects are constantly shaped by their interrelationships (relationality).
(2) Social phenomena and materiality are fused together (interpenetration).
(3) Boundaries between social phenomena and materiality are human-made and often hard to define (agential cuts).

4.2. Approaches to sociomaterial studies

Sociomateriality has a practice-based perspective and is used to study the relationship and influence between human and non-human elements (Moura & Bispo, 2020). When designing a sociomaterial study, an important aspect to consider is the theoretical foundation upon which it will be built (Leonardi, 2013). This thesis adopts the theoretical foundation of critical realism. As an ontological basis, critical realism considers social and material agencies as separate entities and claims that they become sociomaterial in the space of practice through imbrication (Leonardi, 2013). From an epistemological perspective, researchers define "how and why the separate social and material become the "sociomaterial" and persist that way over time" (Leonardi, 2013, pp. 74). Furthermore, critical realism investigates social and material agencies as methodological units, both separately and in their entangled nature (Leonardi, 2013).

Sociomaterial studies adopt mostly qualitative methods but it is not uncommon for quantitative methods to be used as part of a research design. For instance, Bispo (2015) points out that interviews focus mainly on the discourse of participants and put less emphasis on materiality elements. In such cases, a quantitative method may complement the data collection and help understanding the interrelationships of the social and material elements.

A wide spectrum of approaches is available to scholars for studying sociomaterial questions. Moura & Bispo (2020) identified seven theories which embrace sociomaterial approaches: new materialism, actor-network theory, cultural-historical activity theory, complexity theory, spatial theory, organisational aesthetics, and science and technology studies. Within spatial theory, space is considered to be a dynamic environment functioning as scenery for the activities of diverse actors and is shaped by simultaneous practices (Fenwick et al., 2011). Massey (2005, pp. 9) recognises space as a "product of

intentions" that are never finished and are "always under construction". Such continuous construction is achieved through the manipulation of space by social agencies. Hillier (2008) argues that space and social agencies are shaped by each other and that spatial organisations act as places of practice for everyday human activities. In sociomaterial studies, the spatial theory approach aims to understand how physical spaces create the social context and, in turn, how these spaces are manipulated by social agencies (Fenwick, 2014).

> *"Space cannot be considered a simple object of study but rather must be considered as a theoretical possibility for analysis. The focus on questions about how space is developed and used leads to consideration of how to enable, encourage, or inhibit certain practices."*
>
> (Moura & Bispo, 2020, pp. 356)

Since spatial theory is recognised for its potential as an analytical framework for discussing space (Moura & Bispo, 2020), a future aim of this research is to explore how spatial theory may be used in investigating the spatial design of a specific building function. In this thesis, spatial theory is introduced as a reference for further studies and will be explored in ongoing research following this Licentiate thesis. For now, reflections on the outcomes of Studies 1 and 2 are made from a broader sociomaterial perspective.

5. Research design and methods

As introduced in Section 1.3, this thesis adopts an intersubjective approach, with sociomateriality as a school of thought (Groat & Wang, 2013). The research methods follow a mixed methods approach, combining qualitative and quantitative studies. The following sections describe the research design and the specific strategies and tactics used in Studies 1 and 2. The investigations in the two studies focus on three research questions: RQ1- '*How do circular values relate to the current production processes and stakeholder perspectives of the kitchen?',* RQ2 – '*How might spatial characteristics contribute to a circular kitchen design?'* and RQ3 – '*How might a circular kitchen design be understood from a sociomaterial perspective?'.* The overview of the studies and connected research questions, aims, methods and outputs are presented in Table 4.

Table 4 – Overview of the research questions, aims, methods, analysis, and output connected to Studies 1 and 2

Study	Research Questions	Aim	Methods	Analysis	Output
Study 1	RQ1 & RQ3	Understand stakeholder perspective (how and why)	Workshops Interview Focus group	Qualitative content analysis	Paper 1
Study 2	RQ2 & RQ3	Investigate kitchen on the market (what)	Floorplan studies	Quantitative statistical analysis	Paper 2

5.1. Research design

Qualitative research focuses on social and cultural settings and analyses them through an interpretive and inductive process while applying a variety of tactics (Groat and Wang, 2013). Through this approach, the researcher attempts to understand not only the phenomenon but also associated meanings and values (Denzin & Lincoln, 2018). Quantitative research is more concerned with patterns of correlations and cause-and-effect explanations between variables and indicates a deductive process (Groat and Wang, 2013). Such an approach is characterised by an emphasis on naturally occurring patterns, the evaluation of specific variables and the use of statistics.

As part of the research design of this thesis, a mixed methods approach was applied; in conducting the planned studies, qualitative and quantitative approaches were considered. These approaches have strengths and weaknesses, and the research benefits from using the two approaches to complement each other (Groat & Wang, 2013). This mixed approach gives opportunities to gain

insight, not only into what is currently available but also into motivations and underlying relationships behind the facts.

A combined strategy, the so-called two-phase design (Groat and Wang, 2013) was used to establish the research design. The methods of this research combine several strategies into a sequence aimed at building on and complementing the results and findings of the preceding enquiry. The first study aimed to understand the stakeholder perspective and their reasoning and understanding of how the kitchen is designed, built, and installed today. This required a qualitative approach. In the second study, the focus was on the current status of the kitchen and the most common design solutions being realised in apartments. Hence, a quantitative approach was necessary.

5.2. Study 1

The aim was to identify circular value opportunities for a future CE-based kitchen design by examining stakeholder activities and the value proposition associated with Swedish kitchens. Investigating the underlying relations, roles, and processes among stakeholders aided understanding of their preferences and priorities. This study focused on the research question of '*How do circular values relate to the current production processes and stakeholder perspectives of the kitchen?*'.

5.2.1. Data collection – workshop, interviews and focus group

The data was collected between 2018 and 2020 through a workshop, semi-structured interviews, and a focus group session. In a workshop with one of the key industrial partners of the CIK project, stakeholders in the value chain connected to the kitchen were mapped, using a power-interest grid for stakeholder prioritisation (adapted from Mendelow, 1981). The following stakeholders were identified: housing developers, architect firms, real estate agencies, kitchen producers, contractors, and end-users.

Using purposive sampling (Saunders et al., 2016) a number of potential interviewees were approached. The detailed interviewee selection process is available in the method chapter in the appended Paper 1. Ten semi-structured interviews were held during 2019-2020, either in person or online. The questions focused on how kitchens are commissioned, designed, delivered, installed, and sold in multiresidential housing projects in Sweden and the participants shared their views on ideal kitchen designs. The interviews varied in length from 35 to 70 minutes and were conducted in either English or Swedish. All interviews were audio-recorded and later transcribed.

To validate and complement the findings of the interview study, a focus group session was organised with representatives of major clients of the kitchen producer (contracting companies and developers of condominiums). The roles of the participants in their respective organisations were focused on sustainability.

5.2.2. Data analysis – qualitative content analysis and value mapping

Qualitative content analysis (Mayring, 2000; Schreier, 2013) was used to analyse the empirical material derived from the workshop, interviews and focus group session. The aim was to uncover information connected to four themes in connection with the research question: interest (of stakeholders), process map (of the kitchen value chain), roles (of stakeholders) and visions (for an ideal kitchen). These four themes comprised the coding frame, which was continuously expended in case sub-themes emerged. NVivo 12 was used to carry out the analysis.

The outcome was further assessed by applying the VMT (Bocken et al., 2013). Instead of using the tool in a workshop setting with stakeholders, it was employed as an evaluation tool. The aim was to assess the value propositions derived from the empirical data. The stakeholders (housing developers, kitchen producer, architects, contractors, and estate agent) were the network actors, and the end-user was the final costumer. Society was considered a distinct stakeholder segment but, in contrast to Bocken et al. (2013) the environment was regarded as an overarching objective. It was argued that environmental benefits must be treated as central goals and drivers of economic and social value propositions.

The values derived from the coded material were sorted into the three value categories. The definitions of each category (as published in Ollár et al., 2020) is established as follows:

- value captured: positive aspects of the value proposition that can support circularity;
- value missed, destroyed, or wasted: negative aspects of the value proposition that can hinder circularity;
- value opportunities: aspects of the value proposition that have the potential to support circularity, including proposals to improve these aspects.

5.3. Study 2

The aim of Study 2 was to investigate the spatial design of the kitchen and evaluate the adaptive capacity of current design solutions. This was done in order to find the characteristics that need to be considered to achieve a future CE-compatible spatial design. This study focuses on the kitchen as a space and the built-in furniture or appliances are only evaluated partially, in relation to the spatial design of the kitchen. The main research question this study investigated was '*How might spatial characteristics contribute to a circular kitchen design?'*.

5.3.1. Data collection – contemporary apartment floorplans

Contemporary apartment floorplan drawings of multiresidential housing projects were collected from the city planning office of Gothenburg. The building permits for housing projects were initially collected to appear in the forthcoming follow-on volume to the book *Bygglov Göteborg 2016* (Nylander et al., 2019). Year on year, the book series aims to provide a descriptive floorplan analysis of recently built apartment buildings, with the analysis focusing on building-level characteristics (such as building typologies, apartment sizes and architectural qualities of the floorplans). Study 2 complements the future content of the upcoming book with an analysis of kitchen design. The housing projects were included in the studied material, based on the following criteria (as in appended Paper 2):

- It received an approved building permit in 2017.
- It was planned to be built within the city of Gothenburg.
- It was a new building production (renovation and alteration projects were excluded).
- It was a multistorey and multiresidential apartment building (twin houses, terrace houses, and student housing were excluded).
- It had available complete floorplan drawings in the archives (partially documented projects with missing drawings were excluded).

The analysed sample comprised 38 housing projects with 3,624 apartment units and 574 different floorplan variations. In Sweden in 2017, 35,783 apartments were built (Statistics Sweden, 2020a), which means that the studied sample represents more than 10% of the total national production. This study evaluated only the planned layout of the apartments and did not follow up on the results of the construction work.

5.3.2. Data analysis

Floorplans have been widely used to investigate the adaptability of dwellings. Femenias and Geromel (2019) used floorplan analysis to investigate owner-driven alterations to apartments in Sweden. Through a space syntax analysis, they evaluated the generality, specificity and flexibility of the floorplans and, through a quantitative analysis of their questionnaire, reported on statistical data (such as average size of the apartments, common room and kitchen typologies, most frequent alterations). Manum (2005) had a similar approach and used floorplans to study the concepts of generality, specificity, and flexibility of apartments in a Norwegian context. He also used space syntax analysis and quantitative measurements. West examined residential floorplans in the UK to evaluate whether they supported the households' lifestyles and needs. They assessed room dimensions and layouts to evaluate room sizes and furnishability.

Not many enquiries use quantitative approaches (Femenías & Geromel, 2019) and the different studies usually focus on selected spatial characteristics (such as generality and flexibility of rooms or size and furnishability of dwellings). This results in a lack of any comprehensive analytical framework for spatial design. Furthermore, in previous research, the kitchen is one part of the evaluation, results, and discussion but not the main focus of the analysis. To analyse contemporary kitchens in the apartment floorplans, it was first necessary to develop a specially designed analytical framework to assess the kitchen from a spatial perspective.

5.3.2.1. The spatial analytical framework

Based on the spatial characteristics presented in Section 3.3 (Step 1) and following a stepwise approach, a spatial analytical framework was synthesised (Figure 19). Those spatial characteristics which could be assessed in floorplans and are currently less regulated were incorporated into the framework (Step 2). For instance, accessibility was excluded since it is highly regulated and enforced by authorities. Likewise, the work-triangle was not measured since regulations define the necessary minimum dimensions for the different work units and the current trend of shrinking apartment sizes prevents unnecessarily long measurements. Eventually, the following spatial characteristics were chosen for inclusion in the framework: size of kitchen and apartment, room typology, combined kitchen-living room, doors, kitchen typologies, kitchen island, infrastructure, daylight and windows, outdoor spaces, and dining area. A detailed description of the measured spatial characteristics and the connected assessment values can be reviewed in the appended Paper 2. In Step 3, a set of definitions were developed as a means of assessing the spatial characteristics. These definitions were based on the information presented in Section 3.3. The prototype of the spatial analytical framework was tested, iterated, finalised, and used to evaluate 3,624 contemporary apartment floorplans (Step 4).

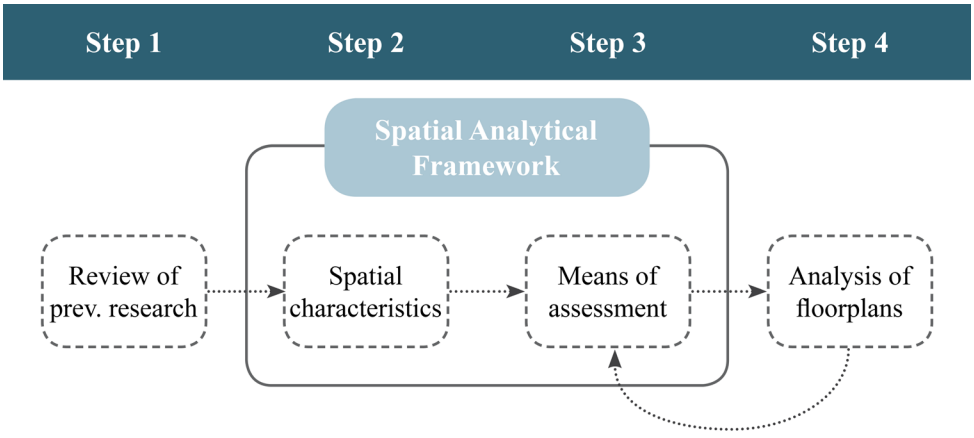

Figure 19 – The iterative process of developing the spatial analytical framework

Besides the spatial design of the kitchen, characteristics (such as apartment size) and statistically relevant information (such as number of apartments, number of rooms) connected to the apartment were also measured. The aim was to later evaluate whether these characteristics and information influenced the kitchen design. Table 5 illustrates a schematic representation of the spatial analytical framework.

Table 5 – Schematic representation of the spatial analytical framework

Spatial Characteristics and Statistically Relevant Information								
Case	**Apartment**				**Kitchen**			
	SC_a1	SC_a2	…	SC_an	SC_k1	SC_k2	…	SC_kn
	AV_{SCa1}	AV_{SCa2}	…	AV_{SCan}	AV_{SCk1}	AV_{SCk2}	…	AV_{SCkn}
C-1								
C-2								
…								
C-n								

SC_a – apartment-related data, SC_k – kitchen-related data, AV – assessment value, C – case reference

5.3.2.2. Adaptability assessment

To apply the adaptive capacity indicators of a specific function of a building, the indicators developed by Geraedts et al. (2014) needed to be adjusted to the building function investigated in this thesis. These adjusted indicators and their definitions (aligned with the kitchen context) are presented in Table 6.

To enable assessment of the apartment floorplans' adaptive capacity, questions were developed based on the adaptive capacity indicators presented in section 3.2.2 (Table 7). Two indicators were not measured: Renew and Rewire. These indicators either had no relevance to spatial changes or were studied as part of another indicator. Strategies for the Renew indicator include tasks that the end-user may achieve easily (such as repainting or exchanging the fronts of the built-in furniture) and do not require spatial changes. The Rewire indicator was studied in the context of the Relocate indicator. The relocation of the kitchen and built-in furniture would automatically require modification of the connected infrastructure outlets.

Table 6 - Overview of adapted indicators and their definitions

Indicators*	Adjusted Indicators	Adjusted Definitions
Quality	Renew	Changing the usability and user experience of the kitchen (e.g., refreshing the look of or exchanging some parts of the built-in furniture)
Redesign	Rearrange	Changing the layout or functions of the kitchen (e.g., altering the kitchen typology)
Relation Internal	Reconfigure	Changing the kitchen's relation with other rooms in the apartment (e.g., opening, removing, or relocating doors or walls)
Grain size		
Facilities	Rewire	Changing the facilities (infrastructure outlets) in the kitchen
Reallocate Internal	Relocate	Changing the location of the kitchen within the apartment
Transfer		
Expansion	Expand or reduce	Changing the kitchen's use surface, increasing, or decreasing its floor area
Rejection		

* as in Geraedts et al. (2014)

Table 7 - Questions assessing the adaptive capacity of contemporary apartment floorplans

Adaptive Capacity Indicator	Assessment Question	Means of Assessment
Rearrange	Is there any other kitchen typology possible within the same kitchen space?	Yes, with minor changes: when only the built-in furniture needs to be changed and infrastructure outlets do not need to be relocated Yes, with major changes: when the infrastructure outlets, doors, or walls need to be relocated in order to accommodate another kitchen typology Otherwise: no
Reconfigure	Is it possible to open new doors towards adjacent rooms which are currently not connected?	Yes: if there is a neighbouring room that is currently not connected to the kitchen with a doorway and there is a lightweight wall between them, and the new door opening would not reduce the furnishability or usability of the rooms Otherwise: no
	Is it possible to remove existing doors or room connections?	Yes: if there is more than one door leading to/from the kitchen and all disconnected rooms are still accessible from another room Otherwise: no
	In combined kitchen-living room: Is it possible to separate the kitchen?	Yes: if there is enough free floor area and, in apartments larger than 55 m^2, if there will be a window in the kitchen after separation Otherwise: no

	In separate kitchen: Is it possible to create a combined kitchen-living room?	Yes: if there is a lightweight interior wall and on the other side of this wall there is a room that could be suitable for a living room area Otherwise: no
Relocate	Is it possible to easily establish the kitchen in another room or in another part of a combined kitchen-living room?	Yes: if a shaft is accessible from another room/part of a room and, in apartments larger than 55 m^2, if there is a window at the new location Otherwise: no
Expand or reduce	Is there a buffer space to expand or reduce the kitchen's floor area over time (without losing a bedroom or living room)?	Yes: with combined kitchen-living rooms, if there is space to take from the living room; with separate kitchens, if there is a lightweight wall that can be moved without reducing the usability of the neighbouring room, if there is an adjacent room (e.g., storage room, not bedroom or living room) that can be merged with the kitchen, or if the floor area of the kitchen can be reduced Otherwise: no

5.4. Reflections on the research design and methods

Groat and Wang (2013) point out that a potential weakness of a two-phased design is that there might be a lack of connection and coherence between the various strategies and tactics. To mitigate this disadvantage, the research designs of the studies in this thesis were developed in close connection with each other: Study 2 aims to deepen understanding of the subject explored in Study 1 while building on the results and discussion of the first enquiry. The strengths and weaknesses associated with the sampling, data collection, analysis, and generalisability of the two studies and two approaches are discussed below.

5.4.1. The qualitative approach of Study 1

The strengths of a qualitative approach include its ability to handle vast quantities of rich data, assess real-life situations and, if necessary, adjust the research design and processes (Groat and Wang, 2013). However, guidelines for conducting qualitative research are open to context-specific adaptation and a qualitative approach is sensitive to interpretations and perceived meanings (Groat and Wang, 2013). To mitigate these weaknesses and establish credible grounds for qualitative research, many researchers have developed rigorous methodologies as a basis for a systematic, reliable research approach (Flick, 2018; Gioia et al., 2012). These methodologies served as inspiration in developing the qualitative approach of Study 1.

The CIK project was a starting point for engaging participants in the activities of Study 1. For the workshop, one direct partner of the project was handpicked, hence, the expertise and perspectives of this partner defined the outcome of the stakeholder mapping. The purposive sampling (Saunders et al., 2016) for

choosing participants for the interview study gave an opportunity to select people with relevant knowledge. Some of the interviewees had ties to the CIK partner and others were selected from alternative circles. This allowed various additional perspectives to be brought into the study. Finally, the focus group session turned the attention back to the partner-specific context since the participants were main clients of the CIK partner. The context-specific investigation enabled a deep understanding of a certain situation. Although, according to Flick (2018), such a case-specific approach might limit the findings and make generalisability difficult.

Methodological triangulation (Flick, 2018, pp. 195) was used to gather a large quantity of data, which was collected through three different tactics: a workshop, interviews, and a focus group session. As Flick (2018) points out, this approach enables a deeper understanding of the studied phenomenon. In Study 1, the findings of the three data collection tactics added to the material discovered in each activity and the focus group session even created validation for the interview outcomes.

The analysis followed the established steps of a qualitative content analysis (Mayring, 2000; Schreier, 2013). This method has the advantage of being able to assess large quantities of data with a thematical focus. The material may be reduced by grouping similar statements under paraphrases (Flick, 2018). Although this analytical method follows a pre-set coding framework, it still allows room for adjustments and additional themes. Compared to other qualitative analysis methods, qualitative content analysis focuses more on reducing the material and less on interpretative processes (Flick, 2018). However, the last step of this method is "presenting and interpreting the findings" (Schreier, 2013, as cited in Flick, 2018), which indicates that this method is still sensitive to the interpretations of researchers.

The qualitative nature of Study 1 enabled the value opportunities to be discovered, value propositions for the kitchen to be summarised and the underlying motivations of the stakeholder to be understood. However, some of the stakeholder statements are context-dependent, which influences the generalisability of the outcomes. Focusing on the Swedish context might have limited the adaptation of results to similar western cultures. Furthermore, studying the kitchen led to findings specific to its space. The kitchen is equipped with certain types of fixed installations (infrastructure, appliances, and built-in furniture) which are not usually part of other rooms. However, the more general results might be easy to adapt to less demanding spatial contexts.

5.4.2. The quantitative approach of Study 2

The strengths of a quantitative approach include the possibility to clarify the relationships between two or more variables and analyse the breadth of a certain phenomenon (Groat and Wang, 2013). However, this approach has no provision

for understanding the depth of the material. In particular, meanings and non-statistical correlations are unlikely to be discovered (Groat and Wang, 2013). Even so, usually well-established and described protocols and procedures are available for quantitative tactics.

By including a large number (n = 3,624) of contemporary apartment floorplans, the sampling facilitated studying the breadth of the investigated phenomenon (spatial characteristics in the light of adaptability and circularity). Once again, narrowing the content of the sample to apartments in a Swedish urban context might have limited the generalisability of the results. However, despite the Swedish context representing a specific snapshot in the field of kitchen and apartment design, there are similarities to designs of other cultures. Hence, it is safe to assume that the findings of this study may be transferred to those similar cultural contexts.

According to Groat and Wang (2013), using archive material as a data-collection method is a typical but less frequently used approach to quantitative research. Archives collect and provide a large range of data which then facilitates studying the breadth of a given phenomenon. Using the archives of Gothenburg's city planning office provided an exhaustive set of apartment floorplans.

The analysis used floorplans to study the spatial characteristics of the kitchen. This limited the evaluation to aspects measurable in a two-dimensional setting and excluded three-dimensional characteristics (such as room height, window placements, artificial light positions, upper cabinets, technical installation of the plumbing and ventilation system and so on). Such a limitation potentially influenced the findings and their generalisability.

6. Study 1 – The stakeholder perspectives

As a first step in investigating the sociomaterial phenomenon connected to the kitchen, this study focused on stakeholder perspectives regarding how kitchens are commissioned, designed, built, delivered, and installed. Furthermore, the stakeholders' view were explored on ideal kitchen designs and their perception of user demands.

The processes and values discovered were then further analysed to reveal circularity opportunities for the built environment. The analysis followed the brainstorming process of Bocken et al. (2015): (1) identifying the stakeholders' collective purpose, (2) identifying positive values; (3) identifying negative values; and (4) turning the negative values into positive ones by proposing improvements. A brief summary of the results of Study 1 is presented below. The detailed outcomes are reported in the appended Paper 1.

6.1. The value chain and value proposition connected to the Swedish kitchen

The Swedish building regulations (National Board of Housing Building and Planning, 2020) require the kitchen (including its built-in furniture and major appliances) to be installed in the apartment upon delivery and remain there when the dwelling changes owners. Therefore, the design and construction processes connected to the kitchen are an integral part of a housing project. These processes were mapped as part of Study 1 and may be summarised as follows.

The housing developer commissions a building project and negotiates with architects regarding the basic design features of the building, layout of apartments and spatial design of the kitchen. The architect then develops the building design, based on the housing developer's instructions and preferences. The kitchen producer is often engaged when detailed drawings are being developed. A building permit is obtained once the building design (including kitchen design) is finalised. The architect leaves the project and the contractor takes over responsibility regarding architectural drawings. Before the construction starts, 30% of a housing project is usually sold (based on drawings, 3D renders or showrooms). A relatively new interior design process is led by the housing developer, who provides a base assortment for the end-user. The end-user can then personalise their kitchen with finishes and material choices but are not allowed to alter the layout or selection of work units. The kitchen is produced once the interior design process is settled. The kitchen furniture are usually delivered to the site fully mounted where they are installed in the apartments.

6.1.1. Stakeholders' purposes within the value chain

As the process shows, except for the housing developer, stakeholders are only taking part in a segment of a housing development. The architect, kitchen

producer and contractor expressed a wish to be part of a longer segment of the development process, or of all of it, to allow them to secure quality, collaborate better and prioritise end-user satisfaction. Although this study revealed some conflicts in the interests of the stakeholders, there were overlapping aspirations too. Their overall purpose may be summarised as:

- creating kitchen furniture, which is aesthetically appealing, complies with regulations and fulfils user needs;
- designing the kitchen as a functional, liveable room;
- developing economically feasible projects with transparent processes and simple logistics.

6.1.2. Values captured

This study identified positive values in current kitchen design. These may serve as a starting point for developing a CE-compatible kitchen design. Table 8 summarises the captured values identified in the value proposition connected with the Swedish kitchen.

Table 8 - Summary of identified captured values for the Swedish kitchen

Stakeholder segments	Value captured (positive aspects of the value proposition that can support circularity)	
Network actors	Furniture and appliance design	Modular design
		Functional furniture
		Practical workflows for working in the kitchen
		Selected base assortment
		Demand for durable materials
		Design harmony and aesthetics
	Spatial design	Open layouts enabling social engagement
		Specific accessibility regulations
		Preferred functional layouts
		Daylight requirements
		Intention to create liveable spatial design
		Small, compact apartments that have less environmental impact
		Dimensions of room determining furniture
		Design harmony and aesthetics
	Processes and economy	Existing partnership agreements
		Well-established collaborations aiming at effective communication
		Rising interest in end-user wishes
		Increased internal sustainability ambitions
		Similar goals and interests among stakeholders
End-user	Demand for long-lasting and energy-efficient appliances	
	Increased interest for technical solutions (e.g., connected apps)	
	Preferences for neutral colours and design	
	Options for end-user choices	
Society	Regulations and standards for good kitchen solutions	
	Extensive regulations connected to apartment design and kitchen	

6.1.3. Values missed, destroyed, or wasted

The identified negative values (Table 9) such as current linear processes, limited user involvement, lack of consideration for the environment and society, more compact living spaces, lack of product and material recovery and strictly applied minimum regulations – represent obstacles on the way to a more circular built environment. These negative values should be improved to achieve a CE-based kitchen design.

Table 9 - Summary of missed, destroyed, or wasted values within the value proposition of the Swedish kitchen

Stakeholder segments	Value missed, destroyed, or wasted (negative aspects of the value proposition that can hinder circularity)	
Network actors	Furniture and appliance design	Modular dimensions of furniture: lack of innovation opportunities
		Unsustainable material use, lack of alternatives
		Lack of correlation between standard measures of appliances and furniture
		Decreased flexibility for renovations due to built-in furniture and appliances
		Quality differences based on location of housing project and target group
	Spatial design	Lack of experimentation and innovation
		Lack of flexibility and adaptability
		Shrinking, more compact apartment sizes
		Strictly following the minimal requirements of regulations leading to inflexible apartments
		Inflexible infrastructure (electricity, plumbing, ventilation)
		Lack of simple separation options for open floorplans
	Processes and economy	Linear process
		Stakeholders are engaged in a limited part of the process, “relay run”
		Hesitant company culture
		Complex and long value and supply chain
		Economic pressure governs (design) decisions
		Furniture usually delivered fully mounted, increased transport
		Sustainability or circularity is not a priority
		Costly repair work to refresh or refurbish furniture
		High precision for installation– increased logistics
		Complex parts of furniture (e.g., long worktops) - difficult to deliver and install
End-user	Lack of direct feedback and evaluation channels	
	Exclusion from design processes	
	Limited options for personalisation (only final finishings)	
	Increased number of electric devices in the kitchen	
	Some demands result in economical or logistical conflicts (e.g., kitchen islands, long worktops without gaps)	
Society	Lack of regulations for more circularity measures	
	Minimum requirements for design of homes (storage, m^2, etc.) being strictly applied as an upper limit	

6.1.4. Value opportunities

Based on suggestions of the interview participants and those of the research team, value opportunities were formulated. These were clustered into four groups: (1) align spatial and product design for circular economy, (2) consider end-user perspectives and demands, (3) formulate regulations based on research outcomes, and (4) develop circular products and services through collaboration (Table 10).

Table 10 - Summary of value opportunities for the kitchen and the built environment

Stakeholder segment	Value opportunities (potentially supporting circularity, including improvement proposals)		Cluster
Network actors	Furniture and appliance design	Long-lasting design[1]	Align spatial and product design for circular economy
		Increased standardisation[1]	
		Practical, functional, aesthetically appealing furniture well-equipped with storage[1]	
		Flexible basic furniture arrangement to enable variety and adaptability[1]	
		Mobile furniture solutions[1]	
		Feasible, durable, sustainable alternative materials which are easy to refresh or renovate[1]	
		Energy-efficient and multifunctional appliances[2]	
		Lifecycle extension of kitchen products[2]	
		Attractive modular worktop solutions with sealed gaps[2]	
	Spatial design	More straight-kitchens and less corners[1]	
		Reasonable spatial margins (e.g., enabling flexibility or kitchen islands)[1]	
		Easy and flexible separation solutions to divide open floorplans[1]	
		Spacious dimensions for number of users and functional workflow[1]	
		Adaptable and flexible layout solutions[1]	
		More flexibility in electricity, plumbing and ventilation infrastructure and outlets[2]	
	Processes and economy	Challenging the idea of delivering kitchens fully assembled[1]	Develop circular products and services through collaboration
		Aligned standards and expand collaborations[2]	
		Understanding long-term market dynamics [2]	
		New business models[2]	
		New partnerships[2]	
		New loops and services (reuse, refurbish, recycle)[2]	
End-user	New feedback channels[1]		Consider end-user perspectives and demands
	Evaluation of user demands[1]		
	Increased user involvement[2]		
Society	New regulations demanding sustainability and circularity[1]		Formulate regulations informed by research
	Regulations possibly requiring reasonably generous dimensions to enable flexibility and adaptability[1]		

[1] Improvement proposals from stakeholders, [2] Improvement proposal from authors based on identified missed, destroyed, and wasted values in line with CE goals

6.2. Summary

This study revealed positive values of the current kitchen design: modular design system, well-established collaborations within the industry, design intentions for proper living spaces, emphasis on spatial qualities, increased interest in end-user perspectives and demand for energy-efficient appliances. These may serve as a starting point for developing a CE-compatible kitchen design. At the same time, the identified negative values – such as the current linear processes, limited user involvement, lack of consideration for the environment and society, more compact living spaces, lack of product and material recovery and strictly applied minimum regulations – need to be improved based on CE-principles.

The study further showed that stakeholders had great knowledge of the spatial characteristics of the kitchen and shared numerous design preferences in connection with them. This gave validation to the focus of this research and further studies were planned, with a greater emphasis on spatial design of the kitchen.

7. Study 2 – Spatial analysis of kitchen and apartment designs

This study examined the material agency connected to the sociomaterial phenomenon of the kitchen. Apartment floorplans were analysed with the aim of identifying current design strategies that are typical of contemporary kitchen design and apartments, evaluating the adaptive capacity of the kitchens, and revealing important spatial characteristics for a future circular kitchen design. A brief summary of the results of Study 2 is presented below. This summary provides a descriptive overview of the most common design solution identified during the analysis of the floorplans. The interpretation of these results is presented in Section 8.2. More detailed findings and connected illustrations are reported in the appended Paper 2.

7.1. Overview of contemporary kitchen and apartment design

Studio (39%) and one-bedroom (32%) apartments comprised more than half of the apartments in the sample. The smallest apartment was 23 m^2, the largest 182.9 m^2 and the average floor was 60.6 m^2. 96% of the apartments had a balcony or terrace. The outdoor spaces were most commonly accessible from the combined kitchen-living room (80%). In apartments with separate kitchens, the outdoor spaces were more often connected to the living room. Although, direct daylight in the apartments was mostly provided from two-perpendicular directions (40%), 81% of studio apartments and 30% of one-bedroom apartments received daylight only through one façade side.

On average, 19% of the apartment's floor area was taken up by the kitchen. The average kitchen floor area was 11.3 m^2. The apartments in the studied sample usually had an open floorplan design (95%). The most popular kitchen typologies were the straight-kitchen (64%) and L-kitchen (31%). U-kitchens (3%) and parallel-kitchens (2%) were seldom planned in the apartments.

54% of the kitchens were accessible by two doors. This created mostly B (pass-through room, 55%) or C (part of one ring, 25%) room typologies. However, the internal ring in the C typology kitchens was often created by a freestanding tall cupboard unit (67% of C typology kitchens). Straight- and L-kitchen typologies were designed usually in pass-through (B) kitchens, parallel-kitchen typologies in C typology rooms and U-kitchens in dead-end (A) rooms.

Only 18% of the kitchens were designed with a freestanding tall cupboard unit and 3% (or 117) of the apartments were planned with a kitchen island. The dining area was most commonly located in the combined kitchen-living room (95%) and had direct daylight connection in 82% of the cases. The kitchens mostly received daylight from one direction (90%).

The infrastructure-dependent appliances (including the sink) were often placed on perimeter walls between apartments (45% of all walls with

infrastructure-dependent appliances) or on lightweight interior walls (35% of all walls with infrastructure-dependent appliances). The shaft (including installations for electricity, plumbing and ventilation) was not directly connected to the kitchen in 36% of the apartments. In other cases, the shaft was in the kitchen (32%) or on its perimeter (22%). The shaft was not clearly indicated on the drawings in 10% of the apartments. Figure 20 illustrates an apartment floorplan with the most typical design solutions found in the studied sample.

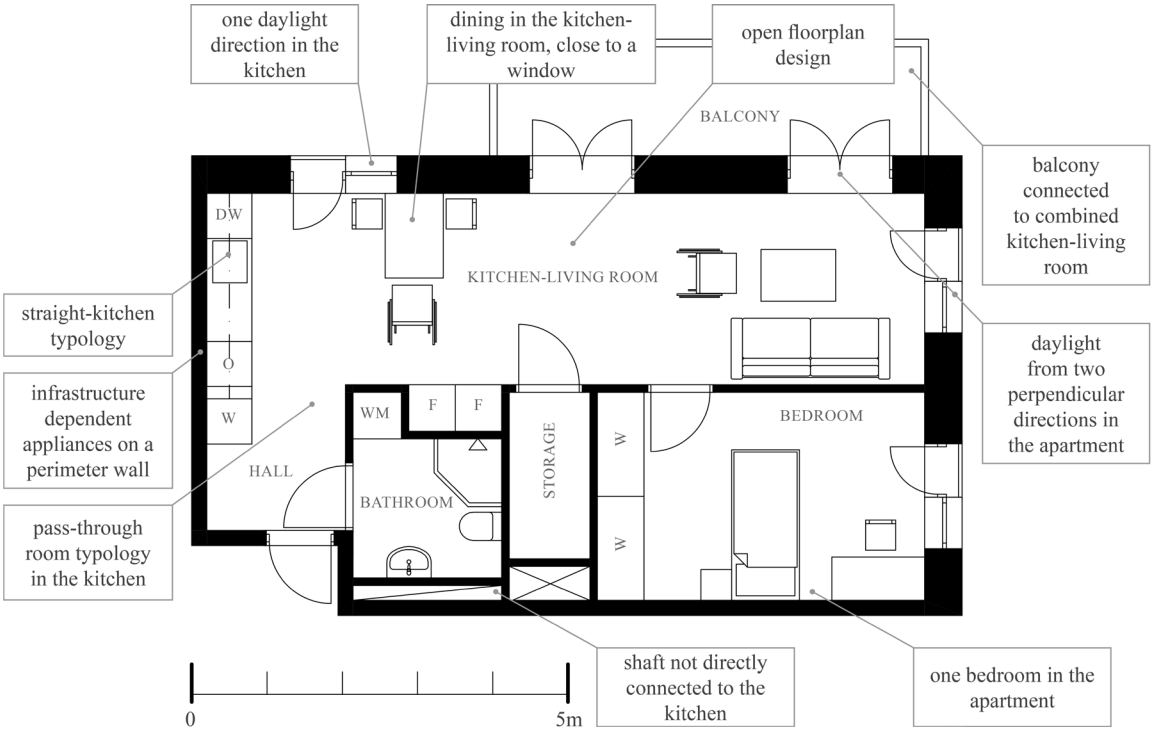

Figure 20 – Apartment floorplan from the studied sample exemplifying the most common design solutions identified during the analysis (DW-dishwasher, F-fridge and freezer, O-oven and stoves, W-wardrobe, WM-washing machine)

7.2. Adaptive capacity assessment

In Study 2, four adaptive capacity indicators were assessed: Rearrange, Reconfigure, Relocate and Expand or reduce. Additionally, design solutions, which enabled or hindered the different indicators, were explored.

The overall results indicated that contemporary apartment floorplans are designed with a relatively good adaptive capacity. It was possible to rearrange the kitchen in 89% of the apartments, to reconfigure by separating (76%) or opening (79%) the kitchen of the applicable apartments and to expand or reduce the kitchen in 76% of the apartments. However, the possibility of relocating the kitchen or reconfiguring by opening or removing door openings were rather limited. Adaptive capacity increased in apartments larger than 55 m^2 and kitchens larger than 10 m^2. Table 11 gives an overview of the adaptive capacity of kitchens in the studied apartment floorplans, with their associated hindering and enabling

design solutions. A detailed description of the findings connected to the adaptive capacity of the kitchens may be found in the appended Paper 2.

Table 11 – Overview of adaptive capacity of kitchens in the studied apartment floorplans

Adaptive Capacity Indicator		Part of the sample with possibilities to adapt	Hindering factors	Enabling design solutions
Rearrange		89%	- lack of space - limited width of the room - existing connections to other rooms	- "squarish" enclosure of the room - continuous interior wall surfaces - larger floor area - fewer traffic zones
Reconfigure	Open new door	4%	- no adjacent unconnected rooms - built-in furniture in the way	- location and number of windows (e.g. multiple windows arranged along a façade side) - room organisation - larger floor area
	Remove existing door	26%	- lack of alternative access to the adjacent room	
	Separate open kitchen	76%	- lack of window access - lack of space	
	Open separate kitchen	79%	- short wall connection between the kitchen and an adjacent room - structural wall in the way - no adjacent room that could function as living room area	
Relocate		32%	- limited shaft access - inability to utilise the current location of the kitchen as another room or function	- shaft access from multiple rooms - multiple shafts in the apartment (e.g., connected to the kitchen or the bathroom) - location and number of windows
Expand or reduce		76%	- lack of space - lack of window access - existing connections to other rooms	- storage room next to the kitchen - open floorplan design - larger floor area

7.3. Summary

The three main contributions of Study 2 are: the analytical framework, the identified typical design solutions for contemporary kitchen and apartment designs and the adaptive capacity assessment of the studied floorplans. The results show that the most typical current apartment designs have one bedroom, a balcony connected to a combined kitchen-living room and daylight from two perpendicular angles. The most typical kitchen design is characterised by a pass-through (B) room typology, with straight built-in furniture located on a perimeter wall and supplied via a shaft not directly connected to the room. The kitchens in the studied sample most often received daylight from one direction and the dining area was often located close to a window.

The adaptive capacity of the apartments in the sample showed relatively good potential, although some indicators performed better than others. There is still a need for improved design solutions to better enable reconfiguration and relocation of the kitchen. The analysis also identified design solutions which might increase the adaptive capacity of the dwellings: “squarish” enclosure of the room, continuous interior wall surfaces, larger floor area, fewer traffic zones, location and number of windows, room organisation, shaft access from multiple rooms, multiple shafts in the apartment, location and number of windows, storage room next to the kitchen or open floorplan design. These design solutions need to be further studied and defined to improve the adaptive capacity of the kitchen and apartments and create a more circular residential building design.

8. Discussion

This chapter discusses the results in connection with the research questions and through the lens of the theoretical framework of sociomateriality. The discussions related to the study-specific questions (RQ1, RQ2) directly contributed to the answer for the overarching question (RQ3). The following sections are organised around the three research questions of this thesis.

8.1. Social agencies of the kitchen

RQ1: How do circular values relate to the current production processes and stakeholder perspectives of the kitchen?

The concept of sociomateriality enabled reflections on the complex relationships within the social agencies of the studied subject. Relationships were explored among stakeholders and in connection with the material agency (the kitchen). The main focus was on how stakeholders look upon the kitchen, what values they identify and how they organise their processes around the material agency. The outcome of the investigations was then further analysed to reveal circular opportunities for the industry. It must be acknowledged that the investigations are a fragment of the whole depiction of the social phenomenon. Study 1 emphasised the perspectives of the stakeholder involved in producing kitchens. However, the interview study included only one end-user. In upcoming studies, the empirical material should be complemented by a more extensive end-user perspective.

The results of Study 1 showed that within the current value proposition of kitchens there is already a wide range of positive values to support a circular housing design. For example, the kitchen producer's efficient processes might serve as a platform for shifting to a more circular business model. The existing modular measurement system of the built-in furniture might enable easy product reparation, refurbishment, reassembly, personalisation, and compatibility between different manufacturers' products. Connecting the modular measurements of the kitchen with other circular design strategies (such as designing for: material reduction, energy reduction, attachment, reliability and durability, ease of maintenance and repair, upgrades and adjustment, disassembly and reassembly, biodegradability and recycling (van Stijn & Gruis, 2019)) - could slow, narrow and close the loops, which are important CE features, as recognised by Bocken et al. (2016).

Despite the existing positive values in the value chain, the missed, destroyed or wasted values identified in the value proposition might hamper a CE transition. The negative values identified in Study 1 are: the industry's linear business model, the hesitant company culture of different stakeholders, the dominant economic focus of organisations, the lost opportunities to capture value, the limited access to user feedback and knowledge on user preferences, the lack of

legislative guidance for sustainability and circularity, the scarcity of practical examples and the shortage of viable circular alternatives, on both product and service level. As this list shows, cultural and market barriers seem to be important, just as Kirchherr et al. (2018) and Hart et al. (2019) observed in their studies. However, technical (such as the need for new machine parks, a lack of sustainable materials) and regulatory barriers (such as a lack of circularity regulations and support for manufacturers in a CE transition) also feed the slow CE transition within the industry. On the positive side, these barriers carry the possibility of being turned into new circular opportunities for the built environment. The four identified circularity opportunities for the built environment are discussed below.

8.1.1. Spatial and product design alignment

The stakeholders highlighted many spatial qualities in connection with the value proposition of kitchens. This indicates that spatial characteristics play an important role in shaping the kitchen and developing circular housing design solutions. The stakeholders demonstrated extensive knowledge in connection with these spatial characteristics (such as functional layouts and room organisation, possible adaptability solutions, accessibility regulations, daylight requirements and need for over-capacity). These characteristics need further exploration to create a CE-compatible spatial design for the kitchen.

As discovered in the literature (Femenías & Geromel, 2019; Hagejärd et al., 2020) contemporary apartment designs are often altered. One of the main reasons for this is social needs, the low-quality materials of built-in products and a lack of adaptability of floorplans that leads to large material flows (Femenías & Geromel, 2019). These issues might potentially be tackled by using some of the study participants' suggestions. For instance, more adaptable apartment floorplans (designed with a reasonable spatial margin) might better accommodate changes and reduce the impact of alterations. Furthermore, additional circular design strategies might enable low-impact personalisation and renovation on both a spatial level (restructuring the floorplan, adaptable infrastructure) and a product level (furniture, appliances, fixtures, windows, doors and so on).

8.1.2. End-user preferences

As found in previous literature, end-user perspectives are an important factor in CE development (Peronard & Ballantyne, 2019) and connected value propositions (den Ouden, 2012). In the current value chain of kitchens in multiresidential building projects, end-users have limited influence on kitchen design. The housing developer and not the end-user is the main client of these projects. Therefore, housing developers' goals and interests play a more important role than end-user preferences. Furthermore, as the participants expressed, kitchen design is influenced by market surveys and real estate broker's experiences, based on what is popular on the market today.

Even though end-users will most likely not be able to participate in the early design process of multiresidential housing, their preferences should be given greater consideration. Previous research has indicated this is necessary to achieve a sustainable, circular built environment (den Ouden, 2012; Peronard & Ballantyne, 2019; Pomponi & Moncaster, 2016). This is important because user preference-based design for multiresidential buildings might enable more adaptability. This, in turn, would help extend the life of kitchens and dwellings, lower the impact of renovations, and reduce resource exploitation.

8.1.3. Research and regulations

Some of the participants in the study implied that current minimum spatial dimensions demanded by regulations do not provide for the necessary room for the needs of households. These dimensions could be increased, which in turn would enable more adaptability and flexibility. However, the current legislations guide the development of housing design in a different direction by allowing and promoting decreasing apartment sizes (National Board of Housing Building and Planning, 2020). Furthermore, the results showed that the economic focus of the building sector sidelines environmental and social considerations. To develop a CE-based building industry, it is important to consider all three pillars of sustainability. These then need to be incorporated into the regulations and thus support organisations in their CE transition.

The extensive housing research of the 1930s to the 1980s (Lee, 2018) produced significant results. Göransdotter and Redström (2018) pointed out that the research conducted by HFI was evidence- and practice-based. This might be the reason why the regulations (based on these research outcomes) are still regarded somewhat positively by stakeholders. Nevertheless, it is necessary to revisit the previous research into housing design and carry out new sets of investigations. Everyday lifestyles have changed in the past few decades and the new sustainability and circularity demands of governmental initiatives are creating new challenges within housing design.

8.1.4. Collaboration for circularity

Although the investigated value chain represents a specific case regarding the design and construction process and cultural context, it exposed issues that have also been discussed in previous literature. Within the value chain of the kitchen, there is a need for strengthened and extended collaborations, as emphasised by Eberhardt et al. (2019). Additionally, stakeholders must rethink their value creation logic to achieve a circular built environment (Nußholz, 2017). The business model connected with kitchens currently has a linear process and favours economic benefits. This model needs to be reorganised and must incorporate environmental and social considerations, as recommended by previous research (Bocken et al., 2013; Evans et al., 2017; Kristensen & Remmen, 2019). The

results also showed that there is a long and complex value chain surrounding the design and construction processes of the kitchen, and that stakeholders only participate in a fragment of it. Stakeholders might exploit currently missed values through extended and strengthened collaboration.

8.2. Material agencies of the kitchen

RQ2: How might spatial characteristics contribute to a circular kitchen design?

Study 2 focused more on the material agencies themselves, to deepen the understanding of the sociomaterial phenomenon connected to the kitchen. The aim was to investigate what kind of kitchens are currently produced in multiresidential buildings and how would these kitchens fit into a new, circular built environment. To evaluate this, the adaptive capacity of kitchens was examined as an important value in connection with circularity (Cheshire, 2016).

8.2.1. The kitchen in contemporary housing design

The results of Study 2 revealed the main spatial characteristics needing consideration when designing a CE-compatible spatial design for the kitchen. As reported in previous literature, the over-capacity of the floor area of apartments and kitchens, window location and distribution, number of door openings and traffic zones and the shaft location all play an important role in enabling adaptability. Study 2 contributes to previous research by recognising the importance of room typology, kitchen typology and the shaft's accessibility as essential spatial characteristics in strengthening the adaptive capacity of kitchens and dwellings.

Most of the studied apartments were designed with a combined kitchen-living room. This design solution enabled expandability since the kitchen could easily spread into the living room or vice versa. However, previous research showed that a large proportion of end-users would prefer a separate kitchen (Tervo & Hirvonen, 2019). Therefore, providing design solutions that allow easy separation of the two rooms would be a desirable quality from the end-user perspective. Study 2 revealed that contemporary apartments offer major opportunities to separate an open kitchen. This is not surprising since Swedish regulations already require that in apartments larger than 55 m^2, the kitchen must be a separable room (National Board of Housing Building and Planning, 2020). On the other hand, Nylander et al. (2019) noted that builders often create apartments just below 55 m^2 so that the kitchen can be placed in a windowless part of the apartment. A positive outcome of the spatial analysis of Study 2 was that, even in apartments smaller than 55 m^2, separation of the kitchen was often possible thanks to numerous well-distributed windows in the apartment. This trend indicates that existing design solutions potentially support adaptable dwellings.

The location and distribution of windows in the apartment was one of the design factors greatly influencing all adaptive capacity of the kitchen. Although kitchens were often designed with a window in the room, the Swedish regulations only require a window for kitchens in apartments larger than 55 m^2 (National Board of Housing Building and Planning, 2020). Hence, smaller apartments had a lower adaptive capacity since in some cases the reconfiguration or relocation of the kitchen was hindered by the lack of window access.

Different room typologies showed different advantages for adaptive capacity. For instance, dead-end (A) and pass-through (B) room typologies allow more opportunity for rearrangement, while C and D typologies (including one or more internal rings) support more options for reconfiguration. There was no clear indication of one room typology (as a recommended design solution) maximising adaptability. However, depending on what adaptive qualities are prioritised, different room typologies may provide a certain increase in adaptive capacity of a dwelling.

The most common kitchen typologies were the straight- and L-kitchens. This is consistent with both stakeholder (as showed in Study 1) and end-user wishes (A. Thiberg, 2007). This coincidence of supply and demand in the market may positively affect CE resource optimisation. When the kitchen is built with design solutions desired by end-users, the need for extensive alterations and personalisation might be reduced.

Kitchen islands and freestanding tall cupboard units were seldom part of the kitchen design. While freestanding tall cupboard units are less favoured by end-users, earlier research has shown that installation of a kitchen island is something that end-users prefer, as these are often added during kitchen renovations. (Femenías & Geromel, 2019). Over-capacity of the kitchen, therefore, is an advantageous feature which would enable lower impact end-user alterations of the space.

Multiple shafts in the apartments (connected to the kitchen or bathroom) enabled relocation of the kitchen to another part of the dwelling. This design solution creates a flexible use of different rooms. Additionally, more flexible, and accessible infrastructure outlets would enable less extensive renovations and associated waste generation.

8.2.2. Design strategies influencing adaptive capacity

The floor area of the kitchen and apartments influenced several spatial characteristics (daylight directions and window access, kitchen floor area, apartment size, presence of kitchen island and freestanding tall cupboard unit, kitchen typology or room typology) and adaptive capacity indicators (Rearrange, Reconfigure, Expand or reduce). Apartments larger than 55 m^2 and kitchens larger than 10 m^2 showed increased adaptive capacity. This finding is consistent with previous research. Femenias & Geromel (2019) found that larger apartments

are renovated more often. This is due to that the over-capacity of spaces allow alterations. However, the results of Study 2 showed that, rather than providing over-capacity, the floor area of apartments is getting smaller. The average floor area of apartments was 60.6 m^2 which is less than the averages reported by other studies (for example, 86 m^2 as in Femenias & Geromel, 2019).

In connection with the floor area of apartments, it is also important to discuss that compact apartment designs do not satisfy end-user demands and are primarily promoted by the market and housing regulations (Tervo & Hirvonen, 2019). Over the decades, rising m^2 sales prices in Sweden (Statistics Sweden, 2020b) have led to a decrease in the affordability of apartments. Furthermore, the extra costs associated with larger apartments (extra resource use, higher energy demand for heating) would become the end-users' responsibility and often create a conflict between economics and comfort.

The results presented in this thesis and Paper 2 reveal that a larger floor area is no guarantee of adaptable housing design, as West & Emmitt (2004) also pointed out. Even in smaller apartments, there were design solutions which supported adaptability. Efficient room organisation (such as avoiding a narrow kitchen right at the entrance), numerous well-distributed windows, shaft access from multiple rooms with windows, adequate width and length of rooms, storage room next to the kitchen, limited traffic zones or continuous interior wall surfaces without doors all enabled alterations to the kitchen or apartment. These design solutions need further investigation to develop concrete strategies for a CE-compatible spatial design.

8.3. Sociomateriality of the kitchen

RQ3: How might a circular kitchen design be understood from a sociomaterial perspective?

In this thesis, the concept of sociomateriality has supported reflections on the complex human and non-human entanglement of the kitchen as a space. It has also helped understand how the social and material agencies have mutually impact each other. On the one hand, how the kitchen is designed and built affects the working processes of the stakeholders and how end-users utilise and retrofit the space. On the other hand, the actions of the stakeholders and end-user preferences and activities connected to the kitchen have shaped how it looks today.

Sociomateriality served primarily as a framework to establish the ontological and epistemological grounds of the Licentiate and as a reflective lens when discussing the outcomes of the included studies. Although applying this framework did not reveal any new findings, it supported a methodological way of organising the results and compelled deeper reflection on the phenomenon being studied. It proved especially useful in dissecting the social and material

agencies, gave a deeper understanding of their elements and highlighted the nature of the relationships between them. Sociomateriality is also a helpful approach to organising the research design of studies. This feature will be further exploited in the continuation of this research.

The results of Studies 1 and 2 showed that there are design solutions already applied in contemporary kitchen and apartment design which would potentially support a CE-based housing design (detailed in Sections 8.38.1 and 8.2). However, the studies also revealed that further improvements and design solutions are needed to achieve a CE in residential building design. A CE-based spatial design for the kitchen would require changes from both social and material agencies. A new circular kitchen design would demand new processes for how kitchens are commissioned, designed, built, delivered, and installed. There is also a need to investigate end-user preferences and create spatial designs that support multiple long lifecycles of residential buildings. Such spatial design will influence kitchen-related tasks and user behaviours. For instance, there might need to be a change and a rethink, not only in how people store raw ingredients, cook or handle food waste, but in how people relate to the kitchen and treat it as a space. The new spatial design of the kitchen must enable and foster less frequent, low-impact renovations and maintenance. For this, more adaptable spatial design of the kitchen is an important feature which requires architects, designers, and all other value chain actors to develop new knowledge and skills. Furthermore, the stakeholders need to find new suppliers (such as sustainable materials and connection solutions that are easy to assemble or disassemble). They also need to adopt new building technologies and implement new business models, to take care of the “re-loops” of a circular system.

At the centre of architecture lies the spatial design of the built environment created by and for humans. Space is developed by people and people are influenced by the spatial organisation in which they live. The main contribution of this thesis is that its studies have revealed spatial design and adaptability as important aspects of a new CE-compatible design for the kitchen. Currently, only parts of the spatial design of the kitchen would enable circularity. Therefore, further investigations would be necessary to define spatial characteristics that would lead to a circular housing design.

9. Conclusions

This thesis has explored two lines of enquiry. Firstly, the value propositions connected to the kitchen were investigated, focusing on stakeholder perspectives. Secondly, the kitchen as a space was examined, with special interest in its adaptive capacity. Both enquiries encircled the concept of CE, aiming to develop knowledge on how to create a more circular housing design.

The methodological contribution of this thesis is the fact that it studies a highly complex phenomenon from a sociomaterial perspective. Additionally, using sociomateriality to reflect on circularity in the context of architectural research contributes to the ongoing discussion of how to transition to CE in the built environment. The mixed (qualitative and quantitative) methods used in the two studies helped elucidate the entanglement of the social and material agencies more than if only qualitative methods had been used. Other sociomaterial studies might apply similar strategies and tactics to enhance their understanding of the phenomena they study.

Study 1 identified several positive values in the value proposition of the kitchen. This may represent a strong basis for a future circular design for the kitchen: *modular design system, well-established collaborations within the industry, design intentions for proper living spaces, emphasis on spatial qualities, increased interest in end-user perspectives and demand for energy-efficient appliances.* Although negative values such as *the current linear processes, limited user involvement, a lack of consideration for the environment and society, more compact living spaces, a lack of product and material recovery and strictly applied minimum requirements in housing design* convey obstacles to a CE transition. Based on the positive and negative values in the value proposition and in line with the studied literature, four circular opportunities were formulated for the built environment: *(1) align spatial and product design for circular economy, (2) consider end-user perspectives and demands, (3) formulate regulations informed by research* and *(4) develop circular products and services through collaboration.* The main conclusion of this study was that more circular design solutions and business models are needed for the kitchen. These would enable more end-user satisfaction, reduce the material flows of renovations, and promote sustainable retrofits.

Study 2 deepened the knowledge of design solutions which could support or hinder a circular housing design. This study presented three main contributions: a new spatial analytical framework, an overview of contemporary kitchen and apartment design and an adaptability assessment of those designs. Although the floor area of the kitchen and apartments seemed to play a significant role in the adaptive capacity of the examined dwellings, it was not the only influencing factor. The findings of Study 2 identified important spatial characteristics which need to be considered while designing a CE-compatible (and hence adaptable) spatial design for the kitchen. This study contributes by identifying the *room*

typology, kitchen typology, and the shaft's accessibility as essential spatial characteristics complementing those already revealed by previous research (*over-capacity of the floor area of apartments and kitchens, window location and distribution, and number of door openings and traffic zones*). In conclusion, a new circular housing design would demand that architects rethink their design strategies, to focus more on solutions that increase the adaptability of dwellings.

With regard to adaptability, this thesis contributes quantitative evidence of the adaptive capacity of contemporary apartment designs. By adopting and testing Geraedts et al.'s (2014) adaptive capacity indicators, the results revealed that current apartments still need further design improvements to increase the adaptability of dwellings in multiresidential buildings. In connection with circularity, an increase in the adaptive capacity of buildings and building functions might provide more opportunities for a resource-efficient built environment (Geldermans et al., 2019; R. Geraedts, 2016; Heidrich et al., 2017). It would further contribute to easier renovation and maintenance which, in turn, might further reduce material flows and resource use. For the field of spatial design, the main contribution of this thesis is the important spatial characteristics of the kitchen that it identified, and the discussion bridging the three research areas: CE, housing adaptability and spatial design.

The combined findings of the two studies indicate that spatial characteristics and their design formulations play an important role in a future circular housing design. For instance, the spatial design of the kitchen might enable less frequent and lower-impact renovations, reduce material flows, and increase end-user satisfaction with apartment designs. However, there is a lack of defining these spatial characteristics in relation to circularity and adaptability. Furthermore, specific design strategies for single building functions need to be developed so that the industry may shift towards a CE in the building sector. There is, therefore, a need for further investigations which finetune the spatial design of the kitchen and develop holistic approaches to a future circular housing design.

10. Further research

The studies presented in this Licentiate outline many possible paths for future research. The values and opportunities discussed in Study 1 potentially need further investigations to weigh their importance. This would produce more information on what aspects of the design and associated processes regarding the kitchen need to be improved. Continued studies might involve more stakeholders and expand the context to other nations. Furthermore, the suggested opportunities need to be incorporated into the design concept of the prototype of a circular kitchen and proof-of-concept testing is necessary to evaluate them. To minimise the negative effects of certain circular design choices would require further study, which examines the trade-offs regarding the application of those choices.

In Study 2, the floorplan analysis focused on evaluating spatial characteristics in a two-dimensional setting. The spatial analytical framework might be extended or complemented by third-dimension-related characteristics (such as room height, window placements, artificial light positions, upper cabinets, technical installation of the plumbing and ventilation system and so on). Such an addition would require expansion of the methods used during the analysis, involving a visual audit or observation of existing spaces, for instance. The results of the spatial analysis might be further analysed. The findings might be differentiated based on apartment types, as the design of smaller and larger apartments have different prerequisites in connection with regulations and end-user demands. Study 2 also served as a testbed for the adjusted adaptive capacity indicators (Geraedts et al., 2014). These indicators were deemed a flexible way of measuring the adaptive capacity of a building function. Just like the analytical framework, the list of indicators and measured characteristics might be further developed with three-dimensional aspects to evaluate an extended variation of aspects of the space.

The two studies both focused on the kitchen, a highly specialised room in the home. Since the results of the two studies might not be directly transferrable to other parts of the home, it is important to initiate further research and expand the investigations to enable a holistic housing design which would support CE. Future research might investigate which spatial characteristics define other spaces in the home and how those spaces may be designed, based on CE principles. Furthermore, the studies did not investigate the retrofitting of existing building stock. Pomponi and Moncaster (2017) point out that the existing housing stock will be part of the built environment for a long time and, proportionally, represents a higher margin than new builds. Therefore, how adaptability might be enabled in existing buildings must be further studied.

Some results of user insight investigations have been already published in connection with the CIK project (Hagejärd et al., 2020). To complement the sociomaterial investigations of this Licentiate, a possible next step might be to further study end-user needs and wishes regarding space. What do they appreciate

in the kitchen as a space? How do they alter it during renovations? Which design features are important to them? These are important questions since understanding the end-user perspective is key, both for value creation (Peronard & Ballantyne, 2019) and for enabling easy alterations and adaptability of dwellings (Heidrich et al., 2017).

The theoretical framework so far has been used as an analytical tool. In further studies, sociomateriality might be included to a greater extent in the research design. Furthermore, the spatial theory introduced in Section 4.2 might be further explored, to ground the theoretical approach of the sociomaterial study of this PhD research.

Based on the identified spatial characteristics, future research must focus on how to define those characteristics and create a CE-compatible spatial design for the kitchen. This line of work will require a research-by-design approach, collaboration with design practitioners and a prototype evaluation of the proposed design solution to verify the concept.

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