# Housing Policies to Promote the Health of a Population Ageing in Place: Comparisons Using Simulation Modelling

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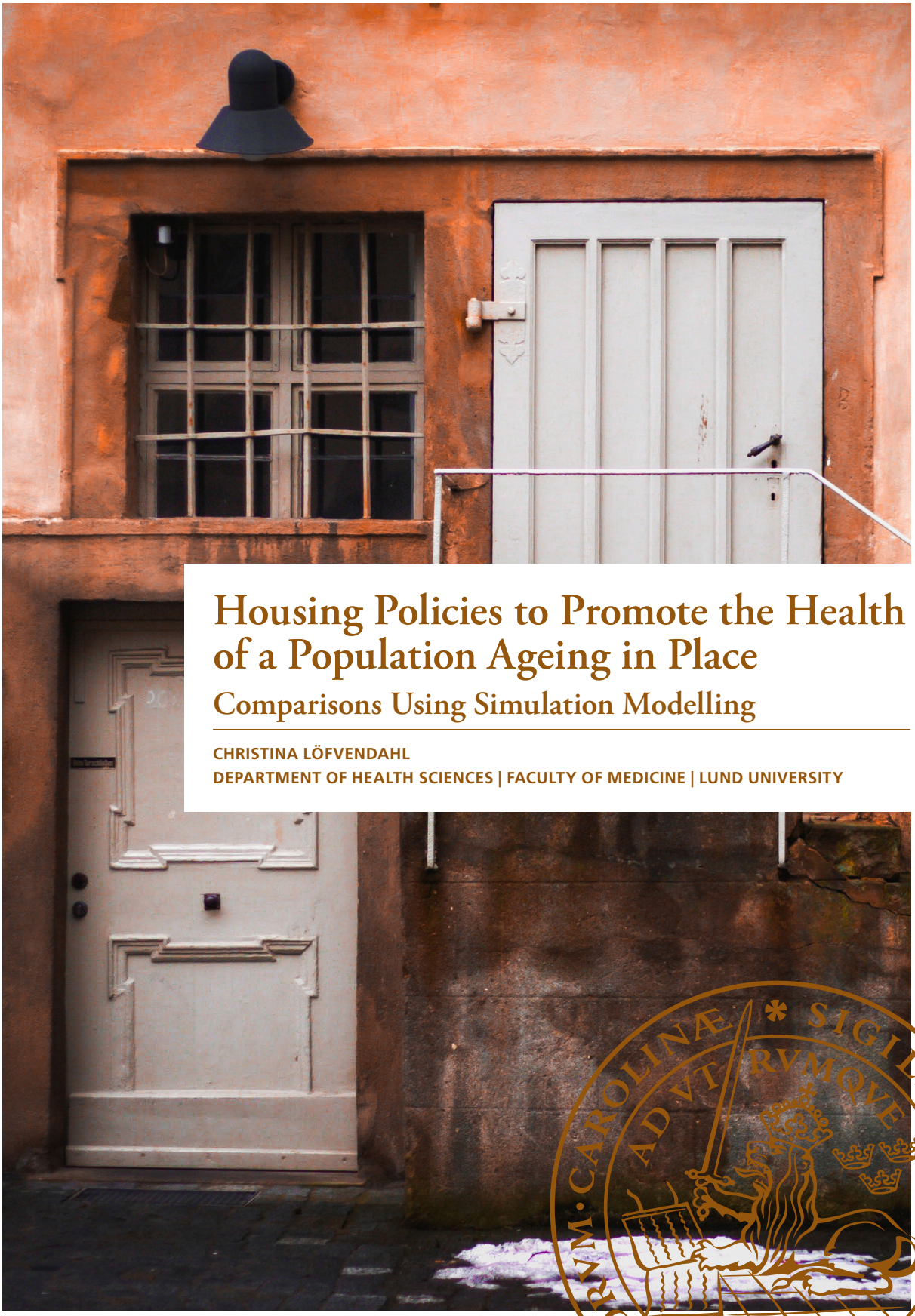

# Housing Policies to Promote the Health of a Population Ageing in Place

## Comparisons Using Simulation Modelling

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# Housing Policies to Promote the Health of a Population Ageing in Place: Comparisons Using Simulation Modelling

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LUND
UNIVERSITY

DOCTORAL DISSERTATION

Doctoral dissertation for the degree of Doctor of Philosophy (PhD) at the Faculty of Medicine at Lund University to be publicly defended on March 7, 2025, at 13:00 in Segerfalksalen, BMC, Lund

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**Title and subtitle:** Housing Policies to Promote the Health of a Population Ageing in Place: Comparisons Using Simulation Modelling

**Abstract:**

**Background:** The Swedish housing stock generally maintains a high standard. However, earlier policies prioritized quantity and rapid housing production targeting a younger population, over policies that require accessible housing design. With an aging population, evidence-based policies supporting ageing in place while managing societal costs are crucial. This thesis aimed to increase the knowledge of housing and housing policies as determinants of health among older people ageing in place. Additionally, it explored how simulation models can be used to analyse and compare consequences in terms of societal gains and costs for different large-scale measures and interventions.

**Material and methods**: The study employed both qualitative and quantitative approaches, aligned with the evidence-based public health framework (EBPHF). Sub-study I (the study protocol) formulated a concise statement of the issue and outlined the development of simulation models. Sub-study II (the policy study) involved semi-structured interviews with key actors from five Swedish municipalities. In a subsequent research circle, those key actors, together with senior citizens and researchers, explored future policy solutions. Sub-study III (the literature review) conducted a systematic review of recent evidence on housing-health relationships among community-living older people. Sub-study IV (the simulation study) performed a cost-benefit analysis using Markov models to assess potential benefits of two new policies, compared to continuing with current policies.

**Results**: The policy study revealed that current housing policies were considered insufficient for the ageing population's needs. Future priorities suggested national coordination of housing accessibility policies and stricter building legislation. The literature review identified three key themes from 15 studies: interventions targeting home modifications, non-intervention studies targeting indoor features, and non-intervention studies targeting entrance features. The overall quality of evidence was assessed as very low. The simulation study showed that new housing policies could prevent or delay ADL (Activities of Daily Living) dependence, allowing older people to remain living independently longer. The large-scale barrier removal policy demonstrated long-term cost-benefits over 20 years compared to current policies, while the home visit with preventive barrier removal policy did not.

**Conclusion**: This thesis provides valuable insights into the impact of housing policies on older adults' health while ageing in place. It emphasizes the need for a multisectoral approach to housing policies within the EBPHF. By addressing environmental barriers and enhancing housing accessibility, policymakers can create more effective strategies to support the population ageing in place, benefitting society as a whole.

**Key words:** Housing policies; ageing in place; health; simulation models; public health; environmental barriers; health economic modelling; activities of daily living; housing acessibility; cost-benefit analysis

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*To my mum Silvia, my son William,*
*my husband Christopher, and my godmother Alexandra*

*"I believe that we have quite a lot [of work] ahead of us that could benefit [the] future [of older people]. We need to make it easier to age in place, and we have a vision that they should be able to do so."– A participant in the interviews*

# Table of contents

# Preface

The cover photo shows an old house in my hometown of Bamberg, Germany. I lived in close proximity to this house during my first working experiences as a nursing assistant, and captured this specific photo at that time. A decade later, this house caught my attention again, as I was working with intensive care patients, who were in need of specialized care in their home environment. As I lived next to this house, I didn't recognize the, in my eyes, small barriers such as stairs or the high thresholds, but I recognized them 10 years later as my patients using a wheelchair could not enter or exit dwellings like this. As a geriatric and intensive care nurse, I have always been passionate about working with older adults. In particular, working with patients in need of intensive care in their home environment has sharpened my critical thinking about environmental barriers, both within- and outside of their home. These barriers, which I had overlooked in the past, were of high importance for my patients to participate in their communities. In my role as a nurse, I could only support them in the environment they lived in; significant changes were rare. I believed that learning more about healthcare management would provide new insights to healthcare organizations, which could optimize patients' daily routines. Therefore, I pursued a Bachelor in Health and Care Management in Nuremberg, Germany. However, I soon recognized that addressing these issues required not just micro- and meso-level approaches, but also a macro-level perspective. I was curious to learn more about macro-level policy dynamics so I believed a Master's in Public Health could increase my knowledge in order to help those patients. Since you are currently reading my doctoral thesis, you may know by now, that my thirst for knowledge remained unsatisfied at this point. I wanted to know even more. I moved to Sweden before the Covid-19 pandemic in autumn 2019 and applied for a PhD position in Lund. When I read the project description, I knew immediately it was the perfect fit for my passions and goals. Thankfully, I was able to spend an intense journey with a project so close to my heart. While my project may not change my previous patients' lives, I firmly believe, that it has the potential to impact the lives of future generations. Much research has been done on housing accessibility, but as one interview participant stated, "I believe that we have quite a lot [of work] ahead of us that could benefit [the] future [of older people]. We need to make it easier to age in place, and we have a vision that they should be able to do so". I share this vision and hope that this thesis contributes to the bigger picture of improving living situations for many people. Furthermore, I hope that this work will make you, as the reader, understand that housing environments and accessibility are crucial health

determinants for all people, but, especially for older adults. Moreover, I hope this thesis inspires you to consider your own living environment and how it can be improved. You may ask if this project finally fulfilled my curiosity about the interplay between health and the environment. Yes, it did, but let's see where it will lead me next. Stay tuned for updates on my journey!

# Context of the thesis

This thesis in medical science with a specialization in public health, focuses primarily on housing and housing policies as determinants of health among older people ageing in place. However, given my background and interdisciplinary working environment, elements of other disciplines such as gerontology, occupational therapy, and epidemiology, will also be applied. The interdisciplinarity is also represented in the author constellation within each sub-study, where the multifaceted views of the co-authors with different backgrounds in public health, occupational therapy, physiotherapy, medical psychology, and health economics contributed to the studies. The PhD project is part of the Forte-financed project Simul-Age, which aims to develop simulation models that enable long-term predictions and analysis of potential consequences in terms of societal gains and costs for different large-scale measures and interventions strategically targeting the ordinary housing stock. This thesis was carried out within the research group Active and Healthy Ageing at the interdisciplinary Centre of Ageing and Supportive Environments (CASE) at the Department of Health Sciences, Faculty of Medicine, Lund University in Sweden. My learning was supported by the Swedish National Graduate School on Ageing and Health (SWEAH).

# List of sub-studies included in the thesis

This thesis is based on the following sub-studies, which will be referred to in the text by their Roman numerals. Please note that the author Christina Heller changed her surname to Löfvendahl between the publication of sub-study III and sub-study IV. The sub-studies are as follows:

*Sub-study I (the study protocol)*

Schmidt, S. M., Chiatti, C., Ekstam, L., Haak, M., **Heller, C.,** Nilsson, M. H., & Slaug, B. (2022). Enabling Long-term Predictions and Cost-benefit Analysis Related to Housing Adaptation Needs for a Population Aging in Place: Protocol for a Simulation Study. *JMIR Research Protocols*, 11(8), e39032. https://doi.org/10.2196/39032

*Sub-study II (the policy study)*

**Heller, C.,** Ekstam, L., Haak, M., Schmidt, S.M., Slaug, B. (2022). Exploring housing policies in five Swedish municipalities: alternatives and priorities. *BMC Public Health*, 22(1), 1-15. https://doi.org/10.1186/s12889-022-12672-5

*Sub-study III (the literature review)*

**Heller, C.,** Haak, M., Schmidt, S.M., Chiatti, C., Ekstam, L., Nilsson, M.H., Slaug, B. (2023). The Relationship between Physical Housing Characteristics, Housing Accessibility and Different Aspects of Health Among Community-Dwelling Older People: A Systematic Review. *Journal of Aging and Health*, 36(1-2), 120-132. https://doi.org/10.1177/08982643231175367

*Sub-study IV (the simulation study)*

**Löfvendahl, C.*,** Schmidt, S.M.*, Chiatti, C., Ekstam, L., Haak, M., Sköldunger, A., Nilsson, M.H., Slaug, B. (2025) Housing Policy Interventions for Community-Dwelling Older People: a Simulation Study Modelling Long-Term Cost-Benefits. *(In manuscript)*.

*shared first authorship

# Thesis at a glance

| Sub-study I: The Study Protocol | |
|---|---|
| **Title** | Enabling Long-term Predictions and Cost-benefit Analysis Related to Housing Adaptation Needs for a Population Ageing in Place: Protocol for a Simulation Study. |
| **Aim** | To outline preparatory steps for the development of simulation models that enable long-term predictions and analysis of potential consequences in terms of societal gains and costs for different large-scale measures and interventions in the ordinary housing stock. |
| **Method** | A simulation study design, that will broadly apply health impact assessment methods in collaboration with five Swedish municipalities. |
| **Results** | As of April 2022, collaboration with five municipalities was established in autumn 2020, open access data were collected, and a systematic review was underway and expected to be completed by November 2022. In spring 2021, the municipalities developed a list of prioritized policy interventions to be tested and used in the simulation models. Inventories of barrier frequencies in ordinary housing started in spring 2022 and were expected to be completed in autumn 2022. Data gathering and analyses for simulation inputs was completed during 2022, followed by the simulation modeling analyses completed in 2023. |
| **Conclusion** | Improved accessibility of the ordinary housing stock has the potential to maintain or improve the health of the ageing population. This study will generate tools that enable long-term predictions and reliable cost-benefit estimates related to the housing adaptation needs for a population ageing in place, thus providing support for the best-informed policy decisions. |
| **Sub-study II: The Policy Study** | |
| **Title** | Exploring Housing Policies in Five Swedish Municipalities: Alternatives and Priorities. |
| **Aim** | To gain an in-depth understanding of how municipalities currently address housing accessibility and to explore what types of policy solutions they consider in the future to better support housing accessibility for the population ageing in place. |
| **Method** | Individual interviews with 10 key actors in five Swedish municipalities, policy documents and a research circle were used to gain an in-depth understanding of current municipal housing policies and to explore what policy solutions are considered for the future. |
| **Results** | A large variety of housing policies were applied from economic incentives to research and development policies, but these were still considered insufficient to meet the needs of the ageing population. As measures for the future, national coordination of housing accessibility policies and sharpening of building legislation were considered to be top priorities. |
| **Conclusion** | The results suggest that collaboration needs to be improved between all actors involved in housing policies. Preventive measures within the current laws may be needed to strengthen the construction of more accessible and affordable housing for populations ageing in place. |

| Sub-study III: The Literature Review | |
|---|---|
| **Title** | The Relationship between Physical Housing Characteristics, Housing Accessibility and Different Aspects of Health among Community-Dwelling Older People: A Systematic Review. |
| **Aim** | To synthesize the evidence on the relationships between physical housing characteristics or housing accessibility and different aspects of health among community-living older people (60 years and older). |
| **Method** | A systematic review with a narrative synthesis approach was conducted. |
| **Results** | Fifteen studies were included that comprised three themes that influence health aspects of community-living older adults: (1) interventions by home modifications targeting housing features both at entrances and indoors; (2) non-intervention studies targeting indoor features;and (3) non-intervention studies targeting entrance features. The quality of evidence for each health outcome across studies was assessed as very low. |
| **Conclusion** | The findings highlight the future need for randomized controlled trials targeting the physical housing environment and health of older adults in order to strengthen the body of evidence and to give adequate recommendations for decision-makers. |
| **Sub-study IV: The Simulation Study** | |
| **Title** | Housing Policy Interventions for Community-Dwelling Older People: a Simulation Study Modelling Long-Term Cost-Benefits. |
| **Aim** | Evaluation of the potential impact of different housing policies on receiving home health services, living in special housing, and living independently among community-living older people. |
| **Method** | The study simulated the impact of two new housing policies – in terms of dependence in activities of daily living (ADL), usage of home services, and related societal costs – by integrating longitudinal empirical data from the longitudinal research databases of the Swedish National study on Aging and Care (SNAC) (N=5,093), publicly available statistics, and scientific evidence gathered in the project. To evaluate the potential cost-benefits of the new housing policies compared to the current policy among community-living older people, Markov models were used. |
| **Results** | Over a 20-year span, a substantial numbers of cases of ADL dependence could be averted or delayed, enabling more people to live independently for a longer time. However, only the large-scale barrier removal policy demonstrated a long-term cost-benefit, while the policy of home visits with preventive barrier removal did not. |
| **Conclusion** | Current housing policies need to be reconsidered in favour of more foresighted and preventive policies, such as the large-scale barrier removal policy. The simulation models constitute a tool that supports informed policy decisions for improved housing accessibility that will in the long-term help to maintain independence among older people who age in their homes, and reduce societal costs. |

# Abstract

**Background**: The Swedish ordinary housing stock generally has a high standard. However, historical housing policies have resulted in a significant proportion of older dwellings with environmental barriers, such as uneven floors or the lack of elevators. As the proportion of older adults continues to grow, there is an increasing need for evidence-based policies that support ageing in place while managing societal costs. Therefore, long-term planning and plausible future projections are needed to support ageing in place and, thereby, the health of the population. This thesis aimed to increase the knowledge of housing and housing policies as determinants of health among older people ageing in place. Additionally, it explored how simulation models can be used to analyse and compare consequences in terms of societal gains and costs for different large-scale measures and interventions.

**Material and methods:** In this thesis, both qualitative and quantitative approaches were used and linked to the evidence-based public health framework (EBPHF). Sub-study I (the study protocol) served as a statement of the issue in terms of the EBPHF and a guide for the following sub-studies by outlining the preparatory steps for the development of simulation models. Sub-study II (the policy study) contributed to three competencies within the EBPHF: community input, quantifying the issue, and prioritization of policy options. To understand current housing policies, two key actors from five Swedish municipalities (N=10) participated in semi-structured interviews. In a next step, those key actors and two senior citizens, as well as three researchers, explored future policy solutions in a research circle. Data were analysed using content analysis. In sub-study III (the literature review), a systematic review of recent evidence on the relationships between housing and various health aspects among community-living older people was conducted. This study addressed the EBPHF competency of determining what is known through scientific literature. In sub-study IV (the simulation study), cost-benefit analysis using Markov models was conducted to assess the potential cost-benefits of two new policies compared to the current care-as-usual policy. The simulation study contributed to the EBPHF competency of evaluating the program or policy.

**Results:** Sub study II: A large variety of housing policies were currently applied from economic incentives to research and development policies, but were still considered insufficient to meet the needs of the ageing population. As measures for the future, national coordination of housing accessibility policies and sharpening of building legislation were considered to be top priorities. Sub-study III: Our review

of 15 studies (from a total of 4,840 records found) identified three key themes addressing physical housing characteristics or housing accessibility that are associated with aspects of health among community-dwelling older adults: (1) interventions by home modifications targeting housing features both at entrances and indoors; (2) non-intervention studies targeting indoor features; (3) non-intervention studies targeting entrance features. The overall quality of evidence was deemed very low across the studies analysed. Sub-study IV: The simulation of new housing policies revealed, that a significant number of cases of ADL dependence could be prevented or delayed, allowing more individuals to live independently for a longer time. However, when comparing the two new policies with care-as-usual over a 20-year period, the cost-benefit analysis yielded divergent results. The large-scale barrier removal policy demonstrated long-term cost-benefits. In contrast, the home visit with preventive barrier removal policy did not exhibit cost-benefits over the same 20-year period when compared to care-as-usual.

**Conclusion:** Housing and health are multidimensional, interrelated, and complex topics. This thesis provides valuable insights into housing policies and their impact on health among older adults ageing in place. By addressing key competencies within the evidence-based public health framework, the thesis highlights the need for a multisectoral approach to housing policies. The study revealed that a large-scale barrier removal policy could potentially delay or prevent cases of dependence, demonstrating long-term cost benefits. By addressing environmental barriers and enhancing housing accessibility, policymakers can create more effective strategies that support the ageing population while benefiting society as a whole.

# Svensk populärvetenskaplig sammanfattning

*Avhandlingens titel: Bostadspolititiska åtgärder för att främja hälsan hos en befolkning som åldras hemma: Jämförelser med hjälp av simuleringsmodeller.*

*Varför behövs denna avhandling?*

Det svenska ordinära bostadsbeståndet håller en hög standard i jämförelse med andra länder, men ändå är utformningen långt från optimal för den ökande andel av äldre som åldras hemma. Sverige står dessutom mitt i en demografisk förändring med en ökande andel av äldre personer som åldras såväl utan som med funktionella begränsningar, såsom nedsatt balans, rörlighet, muskelstyrka men även försämrad syn, hörsel och kognitiva begränsningar. För att möta behoven hos de allt fler äldre som kommer att bo kvar hemma längre och för att underlätta dagliga aktiviteter för personer med olika funktionsförmågor, är det viktigt att det ordinära bostadsbeståndet är lämpligt utformat. Frågor som rör behovet av anpassade bostäder och äldres hälsa är dessutom viktiga ur ett folhälsoperspektiv. Folkhälsa fokuserar på förebyggande och hälsofrämjande insatser för hela befolkningen och har som mål att bidra till ett jämlikt och hälsosamt samhälle. När det gäller äldre personers bostäder har det gjorts många förebyggande och hälsofrämjande insatser, till exempel avseende förbättrad belysning, installation av stödhandtag och rökdetektorer. Trots det kvarstår utmaningar i bostadssituationen för äldre när det gäller tillgänglighetsanpassad bostadsdesign (Granbom et al., 2016; WHO, 2018). I takt med att den svenska befolkningen åldras ökar behovet av att förstå hur bostäder och bostadspolitik påverkar folkhälsan, särskilt bland äldre som vill bo kvar i sina hem.

*Vad är syftet med avhandlingen?*

Denna avhandling har som övergripande syfte att öka förståelsen för hur boende och bostadspolitik påverkar hälsan hos äldre som bor kvar hemma. Genom att använda simuleringsmodeller jämfördes samhällsvinster och kostnader för olika storskaliga åtgärder. Dessa modeller har potential att hjälpa beslutsfattare till exempel på kommunal nivå att fatta välgrundade beslut, och gör det möjligt att jämföra och utvärdera olika insatser innan de implementeras i verkligheten. Genom en implementering av olika bostadspolitiska åtgärder kan dessutom tillgängligheten i

det ordinära bostadsbeståndet förbättras, vilket i sin tur främjar äldres hälsa och bidrar till ett mer inkluderande samhälle.

*Vilka studier ingår i avhandling?*

I denna avhandling ingår fyra delstudier. Delstudie I, är ett så kallad studieprotokoll. Ett studieprotokoll är en omfattande handlingsplan där syftet, metoden och analysen för de kommande studierna motiveras. I studieprotokollet beskrivs hur vi planerar att utveckla simuleringsmodeller för det större projektet "Simul-Age" där denna avhandling ingår. Syftet med studien var att beskriva och motivera de förberedande stegen för utvecklingen av simuleringsmodeller. Det vill säga, protokollet beskriver hur vi planerar att utveckla simuleringsmodeller för att förutspå långsiktiga effekter av olika bostadspolitiska åtgärder inriktade på den ordinära bostadsmarknaden. Delstudie II (policy-studien) utforskar hur aktörer i fem svenska kommuner ser på tillgänglighet i boendet idag och vilka lösningar de ser i framtiden som kan förbättra tillgängligheten i boendet för den åldrande befolkningen. Genom intervjuer, interna policydokument och en forskningscirkel med deltagare från kommunerna och äldre medborgare, fick vi en bättre förståelse för hur kommunerna jobbar med tillänglighetsfrågor idag och vilka lösningar de ser för framtiden. Delstudie III (litteraturgransknings-studien), ville ta reda på hur bostäders fysiska egenskaper och tillgänglighet hänger ihop med olika hälsoaspekter hos personer som är 60 år och äldre som bor hemma. Studien sammanfattar aktuella studier om samband mellan fysiska boendeegenskaper, tillgänglighet i boendet och hälsoaspekter. Denna litteratur-granskning beskriver vad vi vet om hur olika anpassningar av bostaden kan påverka äldres hälsa och förmåga att bo kvar hemma. Den sista studien som ingår i avhandlingen är en simuleringstudie (delstudie IV). Där jämförs nya bostadspolitiska åtgärder med de åtgärder som på det stora hela används idag för att förbättra tillgängligheten för äldre som bor kvar hemma. Genom att simulera effekterna över 20 år kan vi se vilka insatser som ger mest nytta för pengarna och därmed stödja besultsfattare att fatta välinformerade beslut som på sikt kan förbättra folkhälsan.

*Vad kom fram inom dem olika delstudierna?*

Studieprotokollet (delstudie I) är mer av en handlingsplan för de följande delstudierna och saknar därför resultat. Policy-studien (delstudie II) visade att olika bostadspolitiska insatser tillämpades, såsom regelbundna renoveringar och kontinuerligt underhåll, individuella bostadsanpassningar baserade på specifika behov, samt samarbete med privata bostadsaktörer i frågor om bostadsförsörjning, men att dessa ansågs vara otillräckliga för att möta behoven hos den åldrande befolkningen. För framtiden ansågs nationell samordning av riktlinjer för bostäders tillgänglighet och en skärpning av bygglagstiftningen vara av högsta prioritet. Litteraturgransknings-studien (delstudie III) lyfte genom en analys av 15 studier (av totalt 4,840 identifierade) fram tre huvudteman kopplade till hur fysiska bostadsegenskaper och tillgänglighet kan påverka hälsan hos äldre som bor i

ordinära bostäder: (1) interventioner genom anpassningar av entréer och inomhusmiljö; (2) studier utan interventioner som fokuserar på inomhusmiljön; och (3) studier utan interventioner som fokuserar på entrémiljön. Den övergripande evidenskvaliteten bedömdes dock som mycket låg i de analyserade studierna. Simuleringsstudien (delstudie IV) visade att nya bostadspolitiska åtgärder skulle kunna förebygga eller fördröja ett betydande antal fall av beroende i dagliga aktiviteter, vilket skulle möjliggöra för fler personer att självständigt bo kvar hemma längre. Vid en jämförelse av två nya bostadspolitiska åtgärder med att fortsätta med nuvarande bostadspolitiska riktlinjer över en 20-årsperiod, gav kostnads-nyttoanalysen olika resultat. Jämfört med nuvarande bostadspolitiska riktlinjer hade en åtgärd med att i större skala ta bort vissa utvalda miljöhinder långsiktiga ekonomiska fördelar, medan en åtgärd med hembesök och förebyggande borttagning av de miljöhinder som vanligtvis är föremål för bostadsanpassningar inte hade det.

*Hur kan denna kunskap användas i framtiden?*

Avhandlingen belyser vikten av att utveckla en långsiktig och förebyggande bostadspolitik som prioriterar äldres hälsa och välbefinnande. Genom att implementera effektiva bostadspolitiska åtgärder kan man förbättra livskvaliteten för äldre och minska behovet av vård- och hemtjänster. Forskningen understryker vikten av att se bostaden som en avgörande faktor för folkhälsan, särskilt i en tid då befolkningen blir allt äldre. Denna forskning bidrar till en djupare förståelse för hur förbättrad tillgänglighet i boendet kan påverka hälsan hos äldre personer, vilket i sin tur kan leda till mer informerade beslut inom bostadspolitiken och folkhälsan.

# Populärwissenschaftliche Zusammenfassung auf Deutsch

*Titel der Dissertation: Wohnungspolitische Interventionen zur Förderung der Gesundheit einer zu Hause alternden Bevölkerung: Vergleiche mithilfe von Simulationsmodellen*

*Warum bedarf es dieser Dissertation?*

Der schwedische Wohnungsbestand weist im internationalen Vergleich einen hohen Standard auf, dennoch ist dessen Gestaltung für den wachsenden Anteil älterer Menschen, die zu Hause altern, bei weitem nicht optimal. Schweden steht zudem vor einem demografischen Wandel mit einem steigenden Anteil älterer Menschen, die sowohl mit als auch ohne funktionelle Einschränkungen wie vermindertes Gleichgewicht, reduzierte Mobilität oder Seh-, Hör, und Muskelkraft, und kognitiven Beeinträchtigungen altern. Um den Bedürfnissen des zunehmenden Anteils älterer Menschen, die länger zu Hause wohnen werden, gerecht zu werden und um die täglichen Aktivitäten für Menschen mit unterschiedlichen Funktionsfähigkeiten zu erleichtern, ist es von hoher Wichtigkeit, den regulären Haus- und Wohnungsbestand anzupassen. Mit dem regulären Haus- und Wohnungsbestand sind in dieser Dissertation alle schwedischen kommunalen Wohnräume gemeint, mit Ausnahme von Pflegeheimen oder anderen kommunalen Pflegeeinrichtungen. Die Frage des Bedarfs an adäquat angepassten Wohnungen und der Gesundheit älterer Menschen ist ein wichtiges Public Health Thema. Public Health (zu Deutsch: Gesundheitswissenschaft) Initiativen konzentrieren sich auf präventive und gesundheitsfördernde Maßnahmen für die gesamte Bevölkerung und möchten zu einer gerechten und gesunden Gesellschaft beitragen. Im Bereich Public Health wurden bereits zahlreiche Maßnahmen für ältere Menschen umgesetzt. Diese zielen auf die Verbesserung der Wohnqualität und Sicherheit ab und umfassen beispielsweise eine optimierte Beleuchtung, die Installation von Haltegriffen sowie die Anbringung von Rauchmeldern. Dennoch bestehen hinsichtlich barrierefreier Wohnraumgestaltung weiterhin Herausforderungen in der Wohnsituation älterer Menschen (Granbom et al., 2016; WHO, 2018). Mit der Alterung der schwedischen Bevölkerung wächst der Bedarf, zu verstehen, wie Wohnungen und Wohnungspolitik die Gesundheit älterer Menschen, die zu Hause altern möchten, beeinflussen.

*Welches Ziel hat diese Dissertation?*

Das übergreifende Ziel dieser Dissertation ist es, das Verständnis dafür zu vertiefen, wie Wohnen und Wohnungspolicies (oder auch Interventionen) die Gesundheit älterer Menschen, die zu Hause leben, beeinflussen. Durch den Einsatz von Simulationsmodellen als Entscheidungsgrundlage wurden gesellschaftliche Vorteile und Kosten verschiedener Interventionen verglichen. Simulationsmodelle haben das Potenzial, Entscheidungsträgern, beispielsweise auf kommunaler oder nationaler Ebene, zu helfen, fundierte Entscheidungen zu treffen. Weiterhin ermöglichen sie einen Vergleich und eine Bewertung verschiedener Interventionen, bevor diese in der Realität umgesetzt werden. Darüber hinaus kann durch die Implementierung verschiedener Wohnungsanpassungen die Barrierefreiheit im regulären Wohnungsbestand verbessert werden, was wiederum die Gesundheit älterer Menschen fördert und zu einer inklusiveren Gesellschaft beitragen kann.

*Welche Studien sind in der Dissertation enthalten?*

Diese Dissertation umfasst vier Teilstudien. Teilstudie I ist ein Studienprotokoll. Ein Studienprotokoll ist ein umfassender Forschungsplan, der die Zielstellung, die Methode und die Analyse für die kommenden Studien begründet. In diesem Fall wird im Studienprotokoll beschrieben, wie wir planen, Simulationsmodelle für das Projekt "Simul-Age" zu entwickeln, von dem diese Dissertation ein Teil ist. Das Studienprotokoll skizziert, wie wir planen, Simulationsmodelle zu entwickeln, um langfristige Auswirkungen auf Kosten und Nutzen verschiedener Wohnungsanpassungsmaßnahmen für den regulären kommunalen Wohnungsmarkt vorherzusagen. Teilstudie II (die Policystudie) untersucht durch Interviews, Analyse von Policydokumenten und einen Forschungszirkel, wie fünf schwedische Kommunen die Barrierefreiheit heute einschätzen und welche Lösungen sie für die Zukunft sehen, um die Barrierefreiheit im kommunalen Wohnungsbestand für die alternde Bevölkerung zu verbessern. Teilstudie III (die systematische Literaturübersicht) beschreibt, wie verschiedene Wohnungsanpassungen die Gesundheit und die Fähigkeit älterer Menschen, die zu Hause altern möchten, beeinflussen können. Die Studie fasst aktuelle Studien über den Zusammenhang zwischen physischen Wohneigenschaften, Barrierefreiheit, und Gesundheitsaspekten bei älteren Menschen (60 Jahre und älter), die zu Hause leben, zusammen. Die letzte Studie der Dissertation ist eine Simulationsstudie (Teilstudie IV). Sie vergleicht neue innovative wohnungspolitische Interventionen mit den derzeit überwiegend angewandten Interventionen zur Verbesserung der Barrierefreiheit für ältere Menschen in ihrem häuslichen Umfeld. Durch die Simulation über einen Zeitraum von 20 Jahren können wir ermitteln, welche der Interventionen das beste Kosten-Nutzen-Verhältnis bietet. Diese wiederum ermöglicht es, Entscheidungsträgern bei der Formulierung fundierter Strategien zu unterstützen, die langfristig zur Verbesserung der öffentlichen Gesundheit beitragen können.

*Was ist das Ergebnis der verschiedenen Teilstudien?*

Das Studienprotokoll liefert keine Ergebnisse, da es sich um einen Handlungsplan für die folgenden Teilstudien handelt. Die Policystudie zeigte, dass von den fünf schwedischen Kommunen aktuell verschiedene wohnungspolitische Maßnahmen, auch so genannte, Interventionen, angewendet wurden, darunter regelmäßige Renovierungen und Instandhaltungen, individuelle Wohnungsanpassungen basierend auf spezifischen Bedürfnissen sowie die Zusammenarbeit mit privaten Wohnungsanbietern in Fragen der Wohnraumversorgung. Diese Maßnahmen wurden jedoch als unzureichend erachtet, um den Bedürfnissen der alternden Bevölkerung gerecht zu werden. Für die Zukunft wurden die nationale Koordinierung von Barrierefreiheitspolicies und die Verschärfung der Baugesetzgebung als höchste Prioritäten identifiziert. Die systematische Literaturübersicht, basierend auf einer Analyse von 15 Studien (aus insgesamt 4,840 identifizierten) ergab drei Hauptthemen im Zusammenhang mit physischen Wohneigenschaften und Barrierefreiheit, die die Gesundheit älterer Menschen die zu Hause altern, beeinflussen. Diese umfassten Interventionen durch Wohnungsanpassungen, mit einem Fokus auf Eingängen und den Innenwohnraum, Studien ohne Interventionen mit Fokus auf den Innenwohnraum, sowie Studien ohne Interventionen, die sich auf Eingänge konzentrieren. Die Gesamtqualität der Evidenz in den analysierten Studien wurde jedoch als sehr niedrig eingestuft. Die Simulationsstudie zeigte, dass über einen Zeitraum von 20 Jahren eine beträchtliche Anzahl von Fällen der ADL-Abhängigkeit (Abhängigkeit bei Aktivitäten des täglichen Lebens) verhindert oder verzögert werden könnten. ADL umfassen grundlegende Tätigkeiten wie beispielsweise selbstständige Toilettengänge, Nahrungsaufnahme oder Ankleiden. Dies widerum könnte, mehr Menschen ermöglichen, länger selbstständig zu Hause zu leben. Allerdings zeigte nur eine „großangelegte Policy zur Beseitigung von Barrieren im Wohnumfeld“ einen langfristigen Kostenvorteil, während die „Hausbesuch Policy mit präventiver Barrierbeseitigung“ keinen Kostenvorteil, im Vergleich zu bestehenden wohnungspolitischen Maßnahmen aufzeigte.

*Wie kann dieses Wissen in Zukunft genutzt werden?*

Die Dissertation weist auf die Notwendigkeit einer langfristigen und präventiven Planung der Wohnungspolitik hin, welche die Gesundheit älterer Menschen berücksichtigt. Durch die Umsetzung effektiver Interventionen kann die Lebensqualität älterer Menschen verbessert und der Bedarf an Pflegeleistungen reduziert werden. Die Forschung unterstreicht die Bedeutung des Wohnens als entscheidenden Gesundheitsfaktor für Public Health, insbesondere in einer Zeit, in der die Bevölkerung immer älter wird. Diese Forschung trägt zu einem tieferen Verständnis bei, wie Wohnungsanpassungen die Gesundheit älterer Menschen beeinflussen können, was wiederum zu fundierteren Entscheidungen in der Wohnungs- und Gesundheitspolitik führen kann.

# Abbreviations

| | |
|---|---|
| ADL | Activities of Daily Living |
| CDC | Centers for Disease Control and Prevention |
| EBPHF | Evidence-based Public Health Framework |
| EBM | Evidence-based Medicine |
| EPHS | Essential Public Health Services |
| HE | Housing Enabler |
| HVPBR | Home visit with preventive barrier removal policy |
| I-ADL | Instrumental Activities of Daily Living |
| LSBR | Large-scale barrier removal policy |
| RCT | Randomized Controlled Trial |
| SNAC | The Swedish National Study on Aging and Care |
| SPH | Self-perceived Health |
| P-ADL | Personal Activities of Daily Living |
| OECD | Organisation for Economic Co-operation and Development |
| OT | Occupational Therapist |
| OR | Odds Ratio |
| QoL | Quality of Life |
| WHO | World Health Organization |

# Introduction

## Public health context

In a historical context, the public health approaches of disease prevention, tackling malnutrition, and the improvement of sanitation have been present since ancient times. For example, the ancient Greeks, with their focus on the Hippocratic philosophy, found that high standards of community sanitation, personal hygiene, and nutrition were established interventions to improve the health of communities. In Rome, to take another example, clean water supply through aqueducts and city planning were early public health measures in the first century BCE. In times of outbursts of widespread diseases or other threats to population health, such as lower respiratory infections or diabetes, the importance of societal polices has become apparent (Tulchinsky & Varavikova, 2014). A recent example where such public health approaches became even more prominent in both societal policies and research allocation was during the Covid-19 pandemic (Tulchinsky & Varavikova, 2014; WHO, 2023). In the classic definition from the theoretician Winslow (1920), public health has been defined as the "science […] of preventing diseases, prolonging life, and promoting health and efficiency through organized community effort". Since Winslow's theoretical definition, several public health efforts have been made that resulted in the tendency of people to be healthier today than a few hundred years ago. The improvement of nutrition, sanitation, knowledge of healthy and unhealthy behaviours among individuals and groups, and the built environment, by measures taken to maintain or to improve the populations' health are just some examples of public health successes (Schneider, 2020). In order to protect and promote the health of the population in all communities, the essential public health services (EPHS) framework was revised in 2020 by the Centers for Disease Control and Prevention (CDC). To improve the health of the population, three main tasks are at the centre of the framework: assessment of the health of the population; assurance through enabling equitable access to communities, and policy development (CDC, 2023).

Not only the community but the effects of the housing environment on the health of the older population have been previously investigated. Housing conditions play a major role in several health outcomes among older adults such as mortality (Damiens, 2020), participation (Levasseur et al., 2020; Thordardottir et al., 2018), and mental well-being (Guo et al., 2021). Even though many environmental public

health efforts have been made, such as improvements in the housing quality, housing accessibility, or safety features, for example smoke alarms, installation of grab bars or improved lighting, the housing situation for older adults in terms of accessible housing design is still insufficient (Granbom et al., 2016; WHO, 2018). With a higher life expectancy, and thus a higher risk for multimorbidity and functional decline, a housing environment that supports older adults to remain active and to perform activities of daily living independently is needed (WHO, 2015). Moreover, as an increasing number of older adults ages in place, there are higher demands for housing that meets higher standards of accessibility and usability to accommodate the changing needs of older adults (Fox et al., 2017). Since the current literature shows shortcomings in investigating long-term housing policies and their potential effect on health outcomes among older adults (Slaug et al. 2017; Zingmark et al., 2017; Zingmark et al. 2019) further research in the field of public health is necessary to support policymakers to make informed decisions and, thereby promote the health of older people who want to age in place.

# Ageing in place

Within the environmental gerontology realm, ageing in place has become a topic of high significance since the proportion of older adults has increased in many countries (Bigonnesse & Chaudhury, 2020). More than one-fifth (21.1%) of the EU (European Union) population was aged 65 and older in 2022 (Eurostat, 2023). The proportion of older adults will increase even more by the year 2030, when one in six people worldwide will be aged 60 or older (WHO, 2020). This is also reflected by the fact, that nine out of ten people aged 65 and older within the EU tend to live in single-households (Pani-Harreman, et al. 2021). Ageing in place has increasingly become of high importance both for researchers and for policy-makers, since it has the potential to save public expenditure and increase older adult's autonomy, independence, and well-being (Bigonnesse & Chadhury, 2020; Lewis & Buffel, 2020, Van Dijk et al., 2015).

Ageing in place is broad and can be viewed from different angles; there is, therefore, an ongoing scientific discussion on what ageing in place entails and how it can be defined (Pani-Harreman et al., 2021). One definition being used refers only to the possibility for older adults to stay in their own homes as they age, without taking the older adults' wishes into account regarding whether they actually want to age in place or not; Lewis & Buffel (2020) defined ageing in place as "older people remain living in their own homes for as long as possible". In contrast to this rather simplistic view, another definition by Grimmer et al. (2015) takes into account the choices of older adults and the support system required to allow them to age in place. Furthermore, unnecessary placement into hospitals or residential care facilities should be avoided according, to the authors. The definition of ageing in place to be

used in this thesis stems from Grimmer et al. (2015), who defined it as "supporting older people's choices to remain living in their own homes for as long as possible without the need to move to institutional care facilities". Finally, Horner & Boldy (2008) suggested "ageing in place is a positive approach to meeting the needs of older people, supporting them to live independently, or with some assistance, for as long as possible". According to Horner & Boldy (2008), ageing in place is viewed as a positive concept; however, not everyone wants to age in place or has the possibility to do so. For instance, older people's and their caregivers' health may be negatively affected if necessary care is delayed through the desire of the older person or their family members to age in place (Bom et al., 2019; Syse et al., 2022).

The policy ideal for older people to remain living in their own homes as long as possible is also challenged by an inaccessible housing environment with potential barriers inside and outside, that hampers the possibilities of being active and independent. Even in Sweden, with a relatively high housing standard, environmental barriers such as stairs at entrances, high thresholds, or the lack of elevators are not uncommon (Granbom et al., 2016; Slaug, Iwarsson & Granbom, 2024). Those barriers entail the risk for older adults with functional limitations to live independently and to perform their activities of daily living or to retain connections with people in their close environment, such as family and friends (Iwarsson, Horstmann & Slaug, 2007; Mahler et al., 2014; Thordardottir et al. 2018). To host the increasing number of older adults who want to age in place, the housing environment needs to be designed, adapted, or improved so that it supports managing their everyday life in an active and independent manner.

# Housing policies

## Definition of housing policies

In order to understand Swedish housing policies, the term policy must first be defined. There were various suggestions made to define policies during the last decades (Howlett, Ramesh & Perl, 2009). The political scientist Carl J. Friedrich implied that a policy needs an aim, goal, or specific objective (Friedrich, 1968). Dye (1972) criticized this definition a few years later due to the fact one can never be sure whether or not a particular policy action has an underlying goal or if there is a goal, it is specifically mentioned in public agendas. Therefore, Dye (1972) suggests a rather short definition, that also will be used in this thesis: "A policy is anything a government chooses to do or not to do". Despite the shortness of the definition, Dye describes that a government is the agent of the public policy-making process and not a private actor such as a company, organization, or an individual. Furthermore, the definition by Dye states that governments have an active choice to act or not to act (Howlett, Ramesh & Perl, 2009). This implies that there can be a political action

or even a political non-action (Dye, 1972; Howlett, Ramesh & Perl, 2009). A non-action can maintain a status quo or the active governmental choice to do nothing (Howlett, Ramesh & Perl, 2009).

In accordance with the previous definition, governments are the main actors when it comes to the course of action within housing policies, just as any other policies. In line with such reasoning, this thesis adheres to the definition of housing policies as "any action taken by a government […] to influence the processes or outcomes of housing" (Clapham, 2018). Clapham also states that governments can make use of five different mechanisms to intervene in the housing market; that is, through *regulations, direct provision, defining issues and problems, subsidies,* and finally, *non-actions.* First, examples of *regulations* might include the adjustments of rents and laws to provide security of tenure for people with lower incomes or the limit of activities of brokers and investors. Second, the *direct provision* mechanism incorporates the provision of rental or social housing by the government. Third, *defining issues and problems,* sets the scene for public discussions and debates on housing issues. Those policies might be linked to political beliefs and result rather in symbolic effects. For instance, the public discussion and view on housing shortages might differ between countries. The attitude and debates of one country might be linked to the imperfections of the housing market, while in other countries there may be a predominant tendency to view the housing shortage as an individual problem rather than a societal one. Public discussions will therefore guide political decisions. Fourth, financial assistance or so-called *subsidies* include grants for builders or organizations in order to renovate older housing or construct new housing. It can also include the supply of monetary aid for individuals or groups to reduce high expenses such as costs for electricity or rents. The fifth mechanism described is *non-action* (Clapham, 2018; Dye 1972). Non-action is an active choice of the government not to intervene in the housing market, for example through an active choice not to raise taxes (Clapham, 2018). Housing policies also differ in their geographical scale and might not only be of national but also international interest (Clapham, 2018; Urfels, 2022).

## Housing policies in Sweden

The Swedish housing system underwent a drastic change after the end of the Second World War. Sweden faced significant housing challenges during this period, including a shortage of construction materials and low housing standards. These issues were further exacerbated by a rapid population increase, as the post-war baby boom led to increased demand for housing, resulting in overcrowded living conditions. As a response, a state-financed housing provision program, the so-called "Million Homes Program", was introduced in the early 1960s aiming to build a high amount of multi-family dwellings in order to accommodate the increasing population and reduce overcrowding (Urfels, 2022).

Sweden is unique with its universal public housing system, which includes housing provision for all societal groups, and not merely the provision of housing to low-income households, as is the case in Germany or Denmark (State of Housing in Europe, 2021; Urfels, 2022; Granath Hansson, 2021). Furthermore, almost 20% of Sweden's total housing stock and 50% of rental apartments are part of the so-called "public housing Sweden". This entails an interest organisation, for municipal housing companies offering rental apartments for all Swedish citizens and is characterized by the "allmännnyttan", which translates into public utility and should contribute to the public good (Sweden's Public Utility (Sveriges allmännytta), 2023). However, Sweden experienced a shift towards more market-oriented housing policies during the 1970s (Urfels, 2022). This shift hindered the production of new housing, and increased homeownership at the expense of rental apartments. This in turn made it challenging for older adults living in inaccessible single-family homes to find affordable and accessible housing alternatives (Granath Hansson, 2021).

The spatial planning in Sweden occurs at the national, regional, and municipal level. The state outlines frameworks with national objectives, such as the national strategy for sustainable regional growth, for both the county councils and the municipalities (Government Offices Sweden, 2016). The county councils (21 in total) are responsible for regional planning. The municipalities (290 in total) are prescribed by law to create a housing provision plan, which entails a detailed and comprehensive view of how the municipality wants to develop its political vision and housing provision. For instance, the provision of different housing types, such as one-family- houses or rental apartments, referred to as ordinary housing in this thesis. Furthermore, the municipalities have the authority to decide on the implementation of regional plans within their geographical boundaries (Swedish National Board of Housing, Building, and Planning, 2023a).

Besides ageing in place, there are several other initiatives focusing on housing and older adults in Sweden. For instance, some cities in Sweden, such as, Östersund and Gothenburg are members of the age friendly cities and community network introduced by the WHO (2024). Initiatives promoted by this network aim to address barriers to the well-being and participation of older people. One domain mentioned is housing, which should be affordable, well-designed in terms of accessibility, and in close proximity to services and the community. The focus on accessibility is also anchored in Swedish law, in the Act on Housing Adaptation Grants (Lag om bostadsanpassningsbidrag) (2018:222). This law aims to enable people with functional limitations to live independently in their homes through housing adaptation grants administered by the municipalities. Examples of such housing adaptations are removal of thresholds, installation of elevators, ramps, or automatic door openers. Additionally, Swedish law provides various service and health care options for older adults; for instance, meals on wheels, institutional care, such as special housing for people with dementia, or nursing homes. According to the Social Security Act (Socialtjänstlagen) (2001:453), Swedish municipalities are obliged to

provide special housing (in Swedish: särskilt boende) for older adults with dementia, or nursing homes. However, special housing options have decreased significantly over time, while home health services have become more common (Pin & Spini, 2016; Swedish National Board of Health and Welfare, 2023). Therefore, the need to find sustainable solutions to meet the needs of an increasing proportion of older adults ageing in place in the coming years has become urgent.

To summarize, Sweden's housing policy approaches for older adults puts emphasis on enabling independent living through housing adaptations, supportive services, and efforts to improve accessibility in housing (Bergstra, 2021). Despite these endeavours, there is a need for further exploration and comparison of housing policies across different municipalities in Sweden. Future research should, therefore, focus on developing comprehensive methods to evaluate and contrast housing policies, enabling a better understanding of their effectiveness in addressing the housing needs of the population ageing in place.

# Health of the older population

This thesis focuses on several health aspects targeting older people. To place the specific health outcomes into context, a general definition and understanding of health is needed. As early as 1948, the WHO defined health as a "state of complete physical, mental, and social well-being, and not merely the absence of a disease or infirmity" (WHO, 2022). Even though this definition has been criticized widely since its formulation, it is still used by the WHO (Huber et al, 2011; Leonardi, 2018). Mainly, the focus on the term "complete" earned most of the concern in scientific discussions, since the requirement for complete health would imply that one might be unhealthy most of the time and a healthy state is impossible to achieve for people with chronic illness, multimorbidity and older adults with functional limitations (Huber et al., 2011; Leonardi, 2018). As of today, there is a broader understanding of health than just the absence of a disease or infirmity. The ongoing scientific discussions reflect the complex nature of health and the challenges of how it should be defined. Health can have many different components, such as medical, social, economic, or self-reported and what distinguishes health from other related concepts is not always clear (Larson, 1999). Leonardi (2018) states that the complexity of health cannot be captured by one single definition and suggests using each definition as one lens to investigate some aspects of health. Furthermore, he suggests the following definition that also will be used in this thesis: "[…] health […] is the capability to react to all kinds of environmental events having the desired emotional, cognitive, and behavioral responses and avoiding those undesirable ones" (Leonardi, 2018). Leonardi's definition does not focus on health as some sort of state that can be reached and will be completed eventually. Rather, he defines health as an ongoing process. Furthermore, besides an individual's capabilities, Leonardi

also takes the environment into account, which is known for having a big impact on health. In addition to the challenges in defining health, the general assessment of the health of older adults creates difficulties since their health status can vary over time (Chatterji et al., 2015). Additionally, ageing can be seen as a dynamic process that results in a heterogeneous group of older adults with different levels of functioning, chronic conditions, and needs (Nguyen et al, 2021). In this thesis, several health outcomes have been investigated. These are:

- **ADLs** describe the fundamental skills required to independently care for oneself, such as eating, bathing, and mobility (P-ADL) (Katz, 1983), and more complex skills, such as cooking, cleaning, and shopping (I-ADL) (Lawton & Brody, 1969).
- **Body functions**, that is, the physiological and psychological functions of body systems (International Classification of Functioning, Disability and Health (ICF), 2023).
- **Life satisfaction** encompasses a subjective positive and negative assessment of an individual's life as a whole (Delhey, 2004).
- **Mortality**, reports the number of deaths in a certain group of people in a specific period of time (National Institute of Health, 2023).
- **Self-perceived health** describes the subjective health of an individual including physical functioning, lifestyle conditions, severity and prognosis of specific diseases. Furthermore, it encompasses socio-economic, biological, physiological and psychological factors (Maniscalco et al., 2020).
- **Social participation** is defined as "a person's involvement in activities that provide interaction with others in society or the community" (Levasseur et al., 2020).
- **Quality of life** is defined by the WHO (2012) as "individuals' perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns".
- **Well-being** means the subjective experiences of an individual's live with respect to satisfaction, pleasant and unpleasant feelings (Diener & Suh, 1997).

The health outcomes of ADL, body functions, life satisfaction, and social participation were selected as they are emphasized as a priority in public health by the WHO (WHO, 2001; WHO, 2015; WHO, 2018). Mortality, a common measure used in epidemiological and public health studies, was also considered (Damiens, 2020; Gao et al., 2023). Additionally, self-perceived health as an important predictor of health state prognosis and mortality under study in the population of older adults has been repeatedly investigated (Machón et al., 2016; Olsson, Currow & Ekström, 2022).

Overall, by examining these various health outcomes, there is a gap of more recent evidence on the relationship between physical housing characteristics or housing accessibility and different aspects of health with a special emphasis on community-dwelling older adults aged 60 and older. Therefore, this thesis aims to address this gap and has the ambition to improve the development of future housing policy interventions and the health among older adults.

# Theoretical context

## Public health approaches

Public health research investigates complex phenomena, therefore a multitude of models have emerged throughout the years. In this thesis, two public health approaches will be used: the social determinants of health model by Dahlgren and Whitehead (1993) (see Figure 1), and the evidence-based public health framework by Brownson, Fielding & Maylahn (2009) (see Table 1).

*The social determinants of health model*

The social determinants of health model has been widely used for 30 years and is also known as "The Rainbow model" (Dahlgren & Whitehead, 2021). Dahlgren & Whitehead created awareness of health inequities in marginalized groups such as people with low incomes, migrants, women, and older adults (Dahlgren & Whitehead, 1993). The model entails a group of different policy and strategy levels, which have either a promoting, protecting, or threatening impact on health. The four different levels can be seen as layers on top of each other, and include a micro-, meso and macro focus (Dahlgren & Whitehead, 1993; Harrington, Marshall & Müller, 2006). The aim of the four different layers is to translate them into four levels of policy action, as described below.

The **first policy level** requires political action on a national or international level and focuses on long-term structural changes. Besides the social and environmental conditions, it includes, the power relations in society, as well as economic strategies. The **second policy level** aims to improve the living and working conditions at a national, regional, or local level through healthy public or business policies and strategies. The housing conditions might be improved through policies on a regional level and the improvement of the health care provision might be covered through a multisectoral approach. The **third policy level** wants to strengthen the social and community networks and social participation for individuals or groups. At this policy level, the question of "how can individuals or groups collaborate in order to improve their health?" is at the centre of attention. The **fourth policy level** focuses on individual lifestyle factors and health attitudes and how they can be improved to promote the health impact and to reduce health hazards (Dahlgren & Whitehead, 1993; Klemperer, 2015).

The Rainbow model has been deemed useful in the 30 years since its implementation, because of its simplicity and its illustration of the different policy levels. This encouraged new ideas in terms of health improvement and the designation of responsibilities for politics, institutions, and other health-care actors (Klemperer, 2015). Furthermore, the model embodies a multisectoral approach, which proves more effective in practice through collaboration across different policy levels, rather than considering policies in isolation (Dahlgren & Whitehead, 1993). Although the model received some criticism since the different policy levels have been interpreted as a drop-down approach with almost no leeway towards a bottom-up approach, this was never the intention of the authors (Klemperer, 2015). In their strategy document to the WHO, Dahlgren and Whitehead aldready put emphasis on the fact, that strategies can and should be initiated on each of the four policy levels (Dahlgren & Whitehead, 1991). One of the key determinants of health included in the model is the housing environment, and in recent years the role of housing has been highlighted within public health research (see e.g., Shaw, 2004; Fenwick, McDonald & Thomson, 2013; Rolfe et al., 2020). Even though the Rainbow model is an overarching model encompassing many other health determinants besides housing, it has been deemed appropriate for this thesis due to its focus on different policy levels and their impact on health. Both housing policies on different societal levels and health outcomes have been investigated in this thesis.

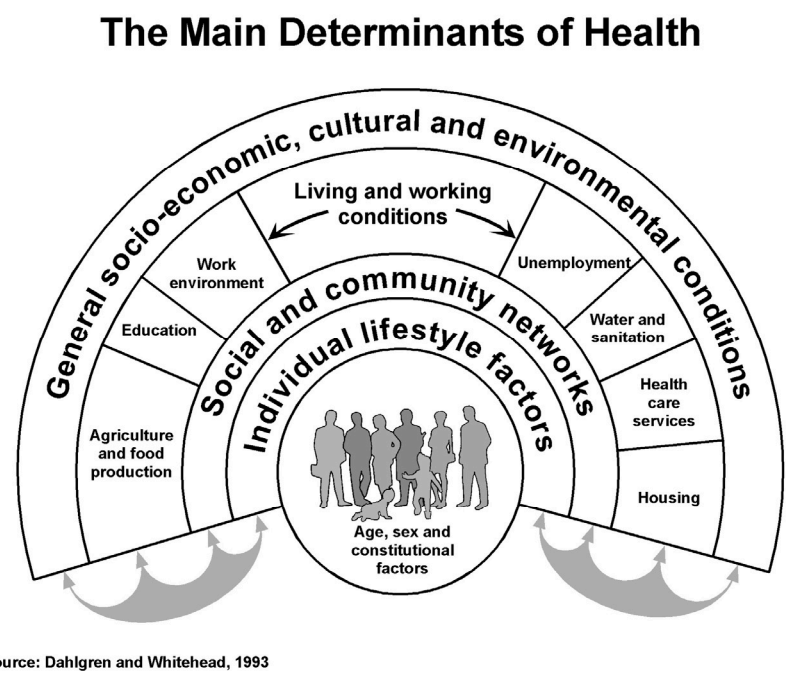


**Figure 1.** The social determinants of health model (Dahlgren & Whitehead, 1993). Reproduced with permission by Dahlgren & Whitehead.

*The evidence-based public health framework*

Evidence-based medicine (EBM) is widely used in Sweden. The cornerstones of EBM are even mentioned in the first chapter §7 of the so-called "patient lag" (Patient Act), which states that the patient must receive healthcare that is of good quality and in accordance with science and proven experience (Swedish Parliament, 2014:821). The aim of EBM is to improve the health situation of individuals. Evidence-based public health (EBPH), on the other hand, wants to implement measures for the entire population to promote health, prevent illness, and improve preparedness for health threats. The EBPH aims to bridge the gap between research and decision-making and a more efficient use of public and private resources. This aim should be achieved through access to the best available knowledge (Rechel et al., 2018). As an addition to the social determinants of health model, the evidence-based public health framework (EBPHF) (Brownson, Fielding & Maylahn, 2009) was deemed appropriate for this thesis. The framework, stemming from the EBM approach, gives concrete suggestions on how policies can be integrated. It can be seen as an addition to the social determinants of health model, where the different policy levels are made visible, but the concrete steps of policy implementation are lacking. Therefore, Brownson, Fielding & Maylahn (2009) suggested a framework with seven steps, in a nonlinear order, which includes specific competencies for the implementation of public health policies. These are, (1) community assessment, (2) quantifying the issue, (3) developing a concise statement of the issue, (4) determining what is known through scientific literature, (5) developing and prioritizing program and policy options, (6) developing an action plan and implementing interventions, and, finally, (7) evaluating the program or policy. In Table 1, the contribution of each study included in this thesis has been structured according to the seven steps of the EBPHF.

**Table 1.** Competencies for policy implementation and contribution of this thesis (adapted from Brownson, Fielding & Maylahn, 2009 and Brownson et al., 2009).

| Category | Competency | Contribution of this thesis |
|---|---|---|
| **Community input** | Before interventions and policies are planned, community engagement is encouraged. Also, community input in other steps of the process should be involved, e.g., the development of interventions or evaluation of their effectiveness. | Input from key-actors and senior citizens was collected through individual interviews and a research circle (sub-study II: the policy study). |
| **Quantifying the issue** | Collection, analysis, and interpretation of data to identify the issue and to comprehend its magnitude. | Data collection on current housing policies and what policy suggestions are needed in the future (sub-study II: the policy study). |
| **Developing a concise statement of the issue** | Articulation of a clear statement of the issue that provides the basis for a policy-setting process. | A statement of the issue has been articulated (sub-study I: the study protocol). |
| **Determining what is known through scientific literature** | Following a systematic literature approach to gain information about the issue. | Synthesis of evidence on the association between housing and health (sub-study III: the literature review). |
| **Developing and prioritizing program and policy options** | Identifying policy options and setting priorities among various alternatives. | Prioritization of policy options (sub-study II: the policy study). |
| **Developing an action plan and implementing interventions** | Developing an action plan that defines the what, how, how much, and who?<br>What goals should be reached?<br>• How will those goals be reached?<br>• How much and what kind of resources are needed?<br>• Who will be responsible? | n/a |
| **Evaluating the program or policy** | Evaluation of the policy to track the outcomes, make improvements or adjustments, and provide information for further programs or policies. | Economic evaluation to compare housing policies (sub-study IV, the simulation study). |

Besides concrete suggestions for policy implementation, the EBPHF aims to increase knowledge among different interest groups for public health interventions, i.e., policymakers at a local, regional, national, or international level, practitioners, or the general public (Brownson, Fielding & Maylahn, 2009). Those groups have a different interest in evidence than researchers. Next to the delivery of high-quality evidence among interest groups, EBPH has the potential for successful intervention implementation through strategic planning and more sustainable use of public and private resources (Brownson et al. 2009; Brownson, Fielding & Maylan, 2009). During the various stages of the EBPHF, it becomes evident, particularly in the systematic review phase, that a substantial body of public health evidence is

available. However, the primary challenge lies in the ineffective translation and communication of these research findings to policy-makers, rather than a paucity of scientific evidence. A reason for the lack of communication could be the differences in the decision-making processes among policy-makers and researchers. The decision-making process among policy-makers is usually based on one single expert opinion or on political considerations, while the best available evidence is at the centre of EBPH decision-making (Sturm, 2002). In order to implement successful evidence-based interventions, the information needs to be adjusted and communicated in a suitable way for policy-makers, who are mostly interested in who has to pay, how much, and who benefits from the intervention (Sturm, 2002). Overall, the EBPH provides a systematic evidence-based policy implementation and relies on the best available evidence, to improve the health of the population.

## A model for the relation between individuals and their environment

Within environmental gerontology and public health, the Ecological model or "competence press model" by Lawton and Nahemow (1973) has been referred to often over several decades (Stokols, 1996; Iwarsson & Ståhl; 2003; Wolf et al., 2021). The term ecology stems from the study of the relationship between organisms and their environment (Stokols, 1996). The cornerstone of the concept is the field theory equation by Kurt Lewin (1936):

$$B = f(P, E)$$

With his field theory function, Lewin postulated that the observed behaviour (B) is a function of both the person (P) and the environment (E) (Lewin, 1936; Scharlach & Diaz Moore, 2016). The suggested function was later refined by Lawton and Nahemow where the interaction term (PxE) was added:

$$B = f(P, E, P \times E)$$

The function now theorizes the behaviour of older adults and their competences in a given environment (Lawton & Nahemow, 1973). The environment can either set environmental press or so-called demands on individuals (Lawton & Nahemow, 1973; Wolf et al., 2021). Thus, a large range of behaviours can be generated by individuals with identical abilities in identical environments (Wolf et al., 2021). As a result of the model, the docility hypothesis (Lawton, 1986) was introduced which states, that individuals with lower competencies will be impacted more by environmental factors in comparison to those with a higher capacity. This means that by changing either the demands of the environment or an individual's capacity, or both, a balance between the components can be achieved. If an individual's functional capacity declines, decreasing demands of the environment have the potential to maintain the individual's capacity. However, higher demands from the

environment on individuals with a lowered capacity would create an imbalance. Although the simplicity of the model has been recognized as important in environmental gerontology and specifically in accessibility research, the competence press model has earned some criticism. Earlier research indicated that a situational factor should be added to the model to address the interaction between the environment and the individual (Wolf et al., 2021). However, the dynamic and simplicity of the original model supported researchers in understanding the relationship between individuals in their environment for many years (Scharlach & Diaz Moore, 2016). Furthermore, the model entails the theoretical assumption that accessible environments for all individuals with or without functional limitations can be reached if the demands of the environment are removed. Since the conceptual models impact all aspects of a simulation-study, including its validity or reliability, a simple but well-established model, such as the Ecological model was deemed appropriate for this thesis.

## Simulation models to mimic real-life interventions

Simulation models are used in various fields, such as engineering, biology, health economics, and public health. The European Commission discussed the underlying research paradigm focusing on simulation models in their report on modelling paradigms of 2018, and raised two important questions: "What is a model?" and "What is a simulation?". On the one hand, a model was defined as "[…] the abstraction of something for the purpose of understanding it" (European Commission, 2018). This captures the basic notion, but is still a bit mystifying and does not clearly distinguish a model from a concept. However, the definition is in line with an earlier attempt from Robinson (2008), who sees a model as an abstraction from a real or proposed system. Taking those two definitions together, we can summarize that to define a model, some kind of abstraction level is needed in order to understand a real or proposed system. Simulations, on the other hand, are a "[…] broad collection of methods and applications to mimic the behaviour of the system under study represented by a model" (European Commission, 2008). In other words, a simulation describes the creation of a virtual environment that behaves like a real-world system. Researchers can then, therefore, test a variety of computer-based scenarios and investigate how the system responds.

Many heterogenic scientific models are still being used, for instance, the Bohr model of atoms or the Gaussian Distribution model. What the models have in common, despite their heterogeneity, is that the aspects of the real world can be identified through elements represented in the model. In other words, there are similarities between the model's elements and the real world. However, it should be noted that the model itself does not claim to represent reality; it is the scientist who interprets wether or not the model represents the aspects of the real world. Giere (2004) states

that scientists choose specific aspects from the model and defines them as some similar features to a real or proposed system.

Within public health research, some study types are prioritized over others. Clinical trials especially are seen as the so-called "gold standard" since they minimize the risk of bias through randomization, and potential effects can already be presented post-intervention (Hansson, 2014). However, simulation models also have the potential to present solutions prior to an intervention, and thereby reduce the risks for participants and save public expenditure by settling for the potentially best treatment or intervention. Especially in health economics − which is based on the "premise of scarcity", meaning that there is a gap between limited resources, e.g., a nurse's time or economic resources and theoretically, limitless wants − an efficient allocation of budgets is needed (Edlin et al., 2015). Simulation models have rarely been utilized in public health research to compare long-term outcomes of different housing policies. This dissertation aims to address this research gap by employing simulation models to evaluate and contrast housing policy options. In conclusion, through the use of simulation models, the response of systems can be investigated, and the best-case scenario could be tested in a real-life intervention, which is crucial in the context of limited resources.

## Analytical model used in this thesis

The methodologies used in this thesis are based on a theoretical model (see Figure 2). The theoretical model stems from an earlier study by Slaug et al. (2017), and has been adapted for the purpose of this thesis. Slaug et al.'s model (2017), made use of Lawton's docility hypothesis. This hypothesis suggests, that individuals with lower functional competencies will be impacted more by environmental demands in comparison to those with higher competencies (Lawton, 1986). Thus, the model entails the theoretical assumption, that housing accessibility depends on the relationship between environmental barriers and an individual's functional limitations. In particular, the combination of environmental barriers and the individual's functional limitations may impact the dependence or independence in I-ADL and P-ADL performance among individuals, which may affect different health outcomes, including living independently, receiving home health services, living in special housing, and death (mortality). Finally, the model entails the theoretical assumption, that accessible environments for those who wish to age in place with or without functional limitations can be reached if the barriers causing the demands of the environment are resolved.

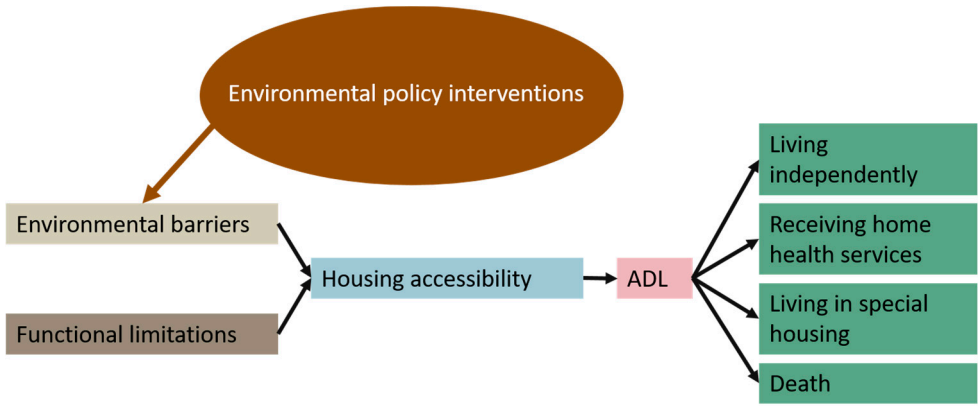


**Figure 2.** Theoretical model (adapted from Slaug et al., 2017).
*Abbreviation: ADL=Activities of Daily Living.*

# Rationale of the thesis

Public health emerged as a discipline before the eighteenth century in a global context, with early efforts concentrating on preventing diseases such as the plague and cholera. Even at this stage, there were public efforts made to protect the health of the population. Some examples are quarantine measures during the 18th century of smallpox patients in the US, and the reporting of deaths. "The Great Sanitary Awakening" describes the sanitation reform in the UK and led to the first reported large-scale measures taken to improve environmental conditions for the population during the 19th century. The sanitation reform gave new insights and knowledge about the importance of sanitary conditions and the reduction of disease spreading (Institute of Medicine, 1988). However, in the modern era, a wide range of determinants of population health has been identified, as illustrated by the social determinants of health model (Dahlgren and Whitehead, 1991). One of the key determinants of health included in the model is the housing environment, and in recent years the role of housing has been highlighted within public health research (see e.g., Fenwick, McDonald & Thomson, 2013; Rolfe et al., 2020; Shaw, 2004).

In particular, the increasing number of older adults in many countries, and the significance of the housing environment to managing their lives actively and independently, has become the focus of several recent research attempts. For instance, studies have shown that older adults exposed to poor housing have an increased risk for a higher frequency of doctor visits (Palacois et al., 2020), decreased mental health, lower quality of life (Ige et al., 2019), and worse well-being (Guo et al., 2021). A few studies with a simulation model design have also been undertaken, analysing various aspects of housing and health of older adults in Sweden. In 2017, Zingmark et al. (2017) conducted a simulation study with a cost-effectiveness Markov-model approach where the authors investigated the long-term costs of a bathing disability intervention. They performed their analysis on hypothetical cohorts of community-dwelling older adults with a bathing disability and followed them over eight years. Quality-adjusted life year (QALY) gains and a reduction of societal costs were found. Two years later, Zingmark et al. (2019) investigated the cost-effectiveness of an intervention focusing on preventive home visits and senior meetings (intervention involving four weekly health-promoting meetings for seniors). In their Markov models, they followed the hypothetical cohorts over four years and indicated QALY gains and lower societal costs. Another Swedish study using a simulation study design investigated the potential costs and

benefits of changes in housing accessibility policies on Instrumental Activities of Daily Living (I-ADL) and the use of home services among community-dwelling people aged 80 to 89 (Slaug et al., 2017).

Despite this growing body of research on housing and health for older adults, significant gaps remain in the understanding of long-term policy impacts and effective interventions. Furthermore, to increase the development of sustainable housing policies and their effect on the health of the older population, a research approach is needed, with the potential to compare long-term housing policy alternatives and the efficient allocation of economic resources. To address this need, this thesis applies a comprehensive approach that combines policy exploration, evidence synthesis, and long-term cost-benefit analysis. Simulation models, and more specifically, cost-benefit analysis, have the potential to provide policy-makers with plausible projections for several years into the future and to make sustainable and informed decisions. The rationale of this thesis is, therefore, an ambition to increase the knowledge of housing and housing policies as determinants of health among older people ageing in place, and to explore how simulation models can be used to analyse and compare consequences in terms of societal gains and costs for different large-scale interventions.

# Aims

The overarching aim of this thesis was to increase the knowledge of housing and housing policies as determinants of health among older people ageing in place, using simulation models to analyse and compare societal gains and costs for different large-scale interventions.

The specific aims were:

- Sub-study I, the study protocol: to outline preparatory steps for the development of simulation models that enable long-term predictions and analysis of potential consequences in terms of societal gains and costs for different large-scale measures and interventions in the ordinary housing stock.
- Sub-study II, the policy study: to gain an in-depth understanding of how municipalities currently address housing accessibility and to explore what types of policy solutions they consider in the future to better support housing accessibility for the population ageing in place.
- Sub-study III, the literature review: to synthesize the evidence on the relationships between physical housing characteristics or housing accessibility and different aspects of health among community-living older people (60 years and older).
- Sub-study IV, the simulation study: to evaluate the potential impact of different housing policies on receiving home health services, living in special housing, and living independently among community-living older people.

# Methods

## Overall study design and context

The thesis has been part of the Forte financed Simul-Age project. Simul-Age aimed to develop simulation models to enable long-term predictions of potential societal consequences, that is, societal gains and costs for a variety of large-scale measures and interventions within the ordinary Swedish housing stock.

A multitude of study designs have been considered in this thesis to increase the knowledge of housing as a determinant of health among older people ageing in place, and to explore how simulation models can be used to analyse and compare consequences in terms of societal gains and costs for different large-scale measures and interventions of the ordinary housing stock in Sweden. The application of a simulation study design has the potential to compare effects of different housing policies based on different scenarios regarding demographic changes, functional limitations, and barriers in the home. Hence, policy-makers can be provided with plausible projections 20 years into the future enabling them to make sustainable and informed decisions and thereby improve the health of the population ageing in place.

The studies included in this thesis apply both qualitative (**sub-studies II** and **III**) and quantitative (**sub-study IV**) research methods. **Sub-study I** provides a research protocol that serves as a guide and overview for the remaining sub-studies. **Sub-study II** applied an explorative study design to gain an in-depth understanding of how municipalities currently address housing policies and what policies they consider in the future in order to address housing accessibility for the population ageing in place. **Sub-study III** was conducted as a systematic literature review in order to gain knowledge on the evidence between housing and health outcomes among community-living older adults. In **sub-study IV,** the results from **sub-studies I, II and III** served as inputs to evaluate the potential impact of different housing policies on health outcomes among community-living older people (see Table 2 and Figure 3). Furthermore, the competencies for policy implementation as suggested by the EBPHF guided the presentation of the data collection, analysis, and the results of this thesis (Brownson, Fielding & Maylahn, 2009; Brownson et al., 2009) (see Table 3).

**Table 2.** Overview of sub-studies I to IV.

| | Sub-study I | Sub-study II | Sub-study III | Sub-study IV |
|---|---|---|---|---|
| | **The study protocol** | **The policy study** | **The literature review** | **The simulation study** |
| **Aim** | To outline preparatory steps for the development of simulation models that enable long-term predictions and analysis of potential consequences in terms of societal gains and costs for different large-scale measures and interventions in the ordinary housing stock. | To gain an in-depth understanding of how municipalities currently address housing accessibility, and to explore what types of policy solutions they consider in the future to better support housing accessibility for the population ageing in place. | To synthesize the evidence on the relationships between physical housing characteristics or housing accessibility and different aspects of health among community-living older people (60 years and older). | To evaluate the potential impact of different housing policies on receiving home health services, living in special housing, and living independently among community-living older people. |
| **Design** | Study protocol | Explorative design | Systematic literature review | Simulation study |
| **Methods** | n/a | Qualitative | Qualitative | Quantitative |
| **Participants/ Sample** | n/a | Ten key actors from five Swedish municipalities, and two senior citizens | Community-dwelling people aged 60 and older | Participants aged 60 and older |
| **Data collection/ Data sources** | n/a | Individual interviews, research circle, policy documents | PubMed, Cinahl, Inspec, Cochrane | SNAC-B, SNAC-K, SNAC-N; Home and Health in the Third Age Study; ENABLE-AGE database; Home and Health in People Ageing with Parkinson's Disease database; Older persons from Hässleholm municipality, living in ordinary housing; Simul-Age inventory; interviews with housing adaptation grant managers; open source data and previously published studies |
| **Analysis** | n/a | Inductive approach, content analysis | Inductive approach, narrative synthesis | Regression analysis, Markov models |

*Abbreviations: n/a=not applicable, SNAC: The Swedish National Study on Aging and Care in Blekinge (B), Nordanstig (N), and Kungsholmen (K).*

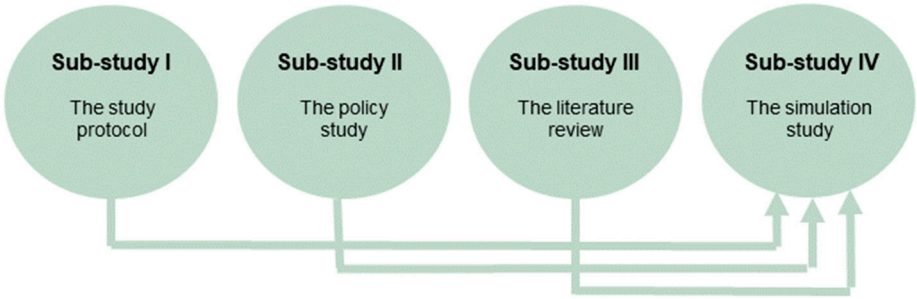


**Figure 3.** Thesis from a study perspective overview.

**Table 3.** Competencies for policy implementation and contribution of this thesis (adapted from Brownson, Fielding & Maylahn, 2009 and Browson et al., 2009).

| Category | Contribution of this thesis | Sub-study |
|---|---|---|
| Community input | Input from key-actors and senior citizens was collected through individual interviews and a research circle. | Sub-study II, the policy study |
| Quantifying the issue | Data collection on current housing policies and what policy suggestions are needed in the future. | Sub-study II, the policy study |
| Developing a concise statement of the issue | A concise statement of the issue has been articulated. | Sub-study I, the study protocol |
| Determining what is known through scientific literature | Synthesis of evidence on the association between housing and health. | Sub-study III, the literature review |
| Developing and prioritizing program and policy options | Prioritizing policy options. | Sub-study II, the policy study |
| Evaluating the program or policy | Modeling long-term cost benefits of housing policy interventions. | Sub-study IV, the simulation study |

# Study protocol as a guide for the following sub-studies

The study protocol (sub-study I), based on the Simul-Age project, outlines the preparatory steps for developing simulation models. This PhD project, while drawing from Simul-Age, incorporates modifications which are detailed in the following sections. In accordance with the protocol, a reference group was established in February 2021. This reference group comprised key stakeholders including housing adaptation grant managers, older adults, and municipal employees specializing in housing policy or adaptation issues. Their input provided valuable feedback on the study methods and highlighted crucial perspectives. A significant outcome of the reference group discussions was the recognition that older adults' views are essential when prioritizing future housing policies.

Consequently, two older adults were invited to participate in the research circle for sub-study II (the policy study). It is important to note that the data collection in the Simul-Age project encompasses a broader range of simulation model inputs (see Table 4 below) compared to those included in sub-study IV, the simulation study (see description in chapter *Simulation model inputs)*. This difference in scope reflects the specific focus of this PhD project within the larger Simul-Age project. Finally, according to the study protocol (sub-study I), the effects of poor accessibility on independence, health, and well-being were planned to be derived from published research results. However, no study explicitly addressed well-being in the systematic review (sub-study II); therefore, this health outcome has not been included in the calculation of the effect sizes in the simulation study (sub-study IV).

**Table 4.** Simulation model inputs according to the study protocol (sub-study I).

| |
|---|
| **1. Costs of housing adaptations** |
| • Publicly available data from 20-30 municipalities<br>• Interviews with housing adaptation grant managers |
| **2. Frequencies/occurrences of environmental barriers in the Swedish housing stock** |
| • Publicly available data from the National Board of Housing, Building, and Planning (Boverket)<br>• Home and Health in People Ageing with Parkinson's Disease database<br>• Housing Enabler inventory in a total of 50 dwellings in five municipalities<br>• SNAC-GÅS (The Swedish National Study on Aging and Care in Scania)<br>• ENABLE-AGE database |
| **3. Population-based functional profiles** |
| • SNAC-GÅS<br>• Scania Public Health Survey<br>• National Public Health Survey from the Swedish Public Health Agency (Folkhälsomyndigheten)<br>• ENABLE-AGE database |
| **4. Costs of existing services** |
| • Statistics Sweden<br>• Swedish National Board of Health and Welfare<br>• Annual economic reports and other material from government, municipalities, counties, or other societal institutions |
| **5. Effects of poor accessibility on independence (ADL), health and well-being** |
| • ENABLE-AGE database<br>• Home and Health in People Ageing with Parkinson's Disease database<br>• SHARE (Survey of Health, Ageing and Retirement in Europe)<br>• SNAC-B, SNAC-N, SNAC-K (The Swedish National Study on Aging and Care in Blekinge, Nordanstig, and Kungsholmen)<br>• SWEOLD (Swedish Panel Study of Living Conditions of the Oldest Old) |

# Municipalities

For this thesis, five Swedish municipalities were selected to participate. The municipalities were chosen purposefully according to diversity in geographic location, population size, socio-economic conditions, proportion of foreign-born inhabitants, and previous collaborations. From a total of 290 Swedish municipalities, Eslöv, Perstorp, Vänersborg, Örebro, and Östersund have been engaged in the research activities (Table 5).

**Table 5.** Overview of the municipalities[1] (Statistics Sweden, 2021).

| Municipality | County | Population size | Density (inhabitants/km2) | Annual median income in Euros | Proportion of foreign-born inhabitants (%) |
|---|---|---|---|---|---|
| Eslöv | Skåne | 34,321 | 81.4 | 26,783 | 19.7 |
| Perstorp | Skåne | 7,465 | 47.1 | 22,255 | 26.4 |
| Vänersborg | Västra Götaland | 39,671 | 61.5 | 26,764 | 15.3 |
| Örebro | Örebro | 156,170 | 113.9 | 27,089 | 18.3 |
| Östersund | Jämtland | 64,194 | 29.0 | 27,365 | 9.4 |

[1] *The annual median income for the year 2019 in Sweden was 28,215 Euros.*

# Participants

In the policy study (sub-study II), we applied a participatory approach and invited 10 key actors with a special knowledge on housing policies from the five Swedish municipalities included in the project (two key actors from each municipality), as well as two senior citizens. The 10 key actors took part in the individual interviews and the research circle. The senior citizens, recruited from a national pensioner organization participated in the research circle that met twice and contributed with their perspectives and suggestions for future housing policies. To provide rich data on housing policies, purposive sampling was applied (Moser & Korstjens, 2018) to recruit the 10 key actors. To capture different areas of responsibilities, we aimed to include participants with a strategic and a housing adaptation focus from each municipality. We considered diversity in terms of age, sex, and professions in our sampling strategy to gain an understanding of different views on current and future housing policies and how these policies should be prioritized. The municipal workers were between 28 and 63 years old (median=43 years) and had on average eight years of municipal working experience. It is important to mention that participant P 01 dropped out after the interview due to a job switch and was replaced by another municipal worker with a similar position within the same municipality

(P 11) when the research circle was conducted. In total, six male key actors (with the replacement) and five female key actors were included in the study. The diversity in sex was also important while recruiting the two senior citizens. Therefore, one man and one woman, aged 74 and 86, were invited to the research circle. All participants were Swedish-speaking (see Table 6).

**Table 6.** Participant characteristics for sub-study II.

| | | | Participation in: | |
|---|---|---|---|---|
| **Participant no.** | **Sex** | **Professional position** | **Individual interview** | **Research circle** |
| P 01 | Male | Development Strategist | x | |
| P 02 | Female | Housing Adaptation Grant Manager | x | x |
| P 03 | Female | Chief of Social Services Department | x | x |
| P 04 | Male | City Architect, Planning, and Construction Manager | x | x |
| P 05 | Male | Program Director Social Welfare | x | x |
| P 06 | Male | Group Leader, Housing Adaptation Grants | x | x |
| P 07 | Female | Mission Strategist in the Health and Care Administration | x | x |
| P 08 | Female | Land and Development Administrator | x | x |
| P 09 | Male | Development Leader Community Planning | x | x |
| P 10 | Male | Housing Adaptation Grant Manager | x | x |
| P 11 | Female | Development Strategist | | x |
| P 12 | Female | Senior Citizen | | x |
| P 13 | Male | Senior Citizen | | x |

# Data collection

In this thesis, data were collected in three studies, that is, the policy study (sub-study II), the literature review (sub-study III), and the simulation study (sub-study IV). The study protocol (sub-study I) primarily describes the data collection for the studies included in this thesis as well as additional studies planned for the overarching Simul-Age project that are not part of this thesis. The data collection was conducted in line with the EBPHF (Brownson, Fielding, & Maylahn, 2009), and contains the following competencies, that is, data collection to engage community input and quantify the issue, data collection to determine what is known through scientific literature, and data collection to develop and prioritize policy options.

## Community input and quantifying the issue

In order to encourage community engagement before developing interventions on housing policies and to quantify the issue, the EBPHF (Brownson, Fielding & Maylahn, 2009) was taken into account to present the data collection in this thesis. Data in the policy study (sub-study II) was collected through individual interviews, a research circle, and policy documents.

*Individual interviews*

To gain an understanding of current housing policies, 10 key actors, such as housing adaptation grant managers and development strategists from five Swedish municipalities were interviewed by CL (Christina Löfvendahl) and LE (Lisa Ekstam). Nine of the 10 semi-structured interviews were conducted during June 2020 and January 2021 online via a video conferencing tool due to the Covid-19 pandemic restrictions, while one interview was held in person. For the interview guide please see *Appendix II.* All the interviews used an interview guide, but the order of the questions was modified to maintain conversation flow. The interviews took approximately 40 to 60 minutes each and were conducted by CL and LE together. Prior to each interview, specifics of each municipality were gathered, including the political and organizational structure and housing supply plans to get a general overview and information of current and future housing accessibility strategies. The interviews were audio-recorded and transcribed verbatim. All personal identifiers were removed. The interviews were chosen as a first step of our data collection as we wanted to elicit the individual participants' experiences and perspectives regarding current housing policies (Moser and Korstjens, 2018).

*Research circle*

In addition to the individual interviews, a research circle, to explore future policy solutions was conducted by CL, MH (Maria Haak), and BS (Björn Slaug). Therefore, the 10 municipal workers, two senior citizens, and three researchers were invited to two meetings two weeks apart during spring 2021. In a first meeting, the preliminary results of the individual interviews, i.e., the current housing policies and interventions to decrease housing accessibility issues, were presented. Since the research circle was conducted during the Covid-19 pandemic, we performed the research circle online via a conference tool and split the participants into two different groups so everyone had a chance to speak and to be heard. In the two different sub-groups, the following question was discussed: "If you could change anything concerning housing accessibility for the population ageing in place, what would you change or improve?". The list of suggestions from each sub-group was summarized by CL, BS, and MH and jointly discussed afterward. The list was then sent out prior to the second meeting, so participants could discuss the suggestions with colleagues or peers for additional input. The second meeting opened with a discussion on the input the participants received from peers or colleagues on the list

of suggestions. In a next step, to quantify the issue, a priority list of the policy suggestions was created by the participants. The research circle meetings were audio recorded and documented with memos by the researchers.

With the research circle, we aimed to explore new ideas and increase the knowledge together as researchers and participants with different backgrounds. The research circle stems from participatory action research and consists of collaborative methods. This methodology has its origin in the Swedish study circle tradition and aims to include different perspectives, competencies, and experiences for the topic under study (Härnsten, 1994). In comparison to the focus group, where the researcher mainly moderates the discussions, the researchers are actively taking part using their knowledge in the research circle discussions (Moser and Korstjens, 2018). The research circle was chosen as part of the data collection since we wanted to collaboratively develop knowledge together as key actors, senior citizens, and researchers.

*Policy documents*

As a part of the strategic planning, each of the 290 municipalities in Sweden is obliged by law to provide a housing supply plan that describes their view of the political vision and housing provision in detail (Swedish National Board of Housing, Building and, Planning, 2023a; Andersén, Berglund-Snodgrass & Högström, 2023). Therefore, in preparation for each individual interview, and to complement the data on current ant future housing policies, the housing supply plans of the five municipalities were utilized. The publicly available housing supply plans were either retrieved from the municipalities' website or received from the key actors involved.

## What is known through scientific literature

The data for the literature review (sub-study III) was drawn from several databases that capture health aspects, housing, and the built environment, including PubMed, Cumulative Index to Nursing and Allied Health Literature (Cinahl), Inspec, and Cochrane Database of Systematic Reviews. A piloted search strategy was conducted in December 2021 by CL and a librarian, therefore the filter function was used in the systematic search to exclude studies outside of our research interest, including those that mainly focused on Covid-19 vaccines, nutrition, palliative care, assisted living, and oral health. To capture more recent studies, a systematic search of studies published between 2010 and 2021 was conducted by CL, BS, and a librarian in January 2022. A combination of search terms according to the PICO model focusing on older adults, health outcomes, and housing has been used and adjusted for each database. The search was also limited to English articles and older adults aged 60 and older.

## Developing, prioritizing, and evaluating program and policy options

*Simulated housing policy scenarios*

In the policy study (sub-study II), the five Swedish municipalities prioritized a variety of housing policies ranging from organizational policies such as improving dialogue and collaboration between different actors, to preventive policies (Heller et al., 2022). From these priorities, two were selected for the simulation comparison, these are, home visit with preventive barrier removal policy, and large-scale barrier removal policy, and then compared to the current care-as-usual policy. Table 7 provides a detailed overview of these simulated housing policies, including their target groups, interventions, and specific environmental modifications. These policies were chosen based on their expected impact on the health outcomes (living independently, receiving home health services, living in special housing, and death (mortality) among older adults and should strategically target the ordinary housing stock in Sweden.

**Table 7.** Overview of the simulated housing policies.

| Policy | Description |
|---|---|
| Care-as-usual policy | • A 1,5-hour preventive home visit conducted by an occupational therapist<br>• Target group: people aged 65 and older living at home without any home health care services<br>• Intervention: average cost of housing adaptations |
| Home visit with preventive barrier removal policy | • A total two-hour preventive home visit conducted by an occupational therapist (extending the standard care-as-usual visit by 30 minutes)<br>• Target group: people aged 65 and older living at home without any home health care services.<br>• Intervention: in an assessment of the housing environment the four most common environmental barriers will be removed:<br>o removal of thresholds<br>o installation of grab bars<br>o replacement of high-kerb shower stalls with level-entry or low-threshold designs<br>o installation of shower space, where a bathtub is installed |
| Large-scale barrier removal policy | • Removal of four barriers among peopl aged 65 and older who are at risk of I-ADL/P-ADL dependence as a preventive measure<br>• Intervention: a subset of four barriers with a high impact will be removed<br>o no grab bar at shower/bath and/or toilet<br>o wash-basin placed at a height for use only when standing<br>o toilet 47 cm or lower<br>o steps/thresholds/differences in level between rooms/floor spaces |

*Care-as-usual policy*

The-care-as-usual policy is intended to reflect the current policy approach and entails the installation of housing adaptations based on individual needs, since every citizen in Sweden has the right to a housing adaptation grant. The prerequisites are that the person lives in a residence with tenancy or tenant's rights and with permanent or long-term functional limitations. The housing adaptation grants need to be applied for before any adaptations are carried out (Swedish National Board of Housing, Building and Planning, 2023a; Swedish National Board of Housing, Building and, Planning, 2023b). This care-as-usual policy encompasses a preventive home visit lasting approximately 1.5 hours for individuals aged 65 and older who are not utilizing any home or care services. These visits are usually conducted by occupational therapists, nurses, or social workers (Swedish National Board of Health and Welfare, 2023). The duration of the visit is based on earlier research on preventive home visits conducted by Sahlen et al. (2006). Our care-as-usual policy scenario involves an assessment of the housing environment by an OT according to guidelines from the Swedish National Board of Health and Welfare (2023). To obtain a comprehensive national perspective on the costs associated with housing adaptations, we utilized the average cost data from the most recent report by the Swedish National Board of Housing, Building, and Planning (2023).

*Home visit with preventive barrier removal policy*

The home visit with preventive barrier removal policy extends the care-as-usual approach by increasing the duration of preventive home visits by an OT by 30 minutes, giving a total of visit time of 2 hours and focusing on removing the four most common environmental barriers in both one-family houses and apartments as a preventive measure: 1) removal of thresholds, 2) installation of grab bars, 3) replacement of high-kerb shower stalls with level-entry or low-threshold designs, and 4) installation of a shower space where a bathtub is installed (Swedish National Board of Housing, Building, and Planning, 2023). This policy targets people aged 65 and older living at home without home health care services.

*Large-scale barrier removal policy*

The large-scale barrier removal policy focuses on the removal of environmental barriers that significantly impact accessibility for people aged 65 and older, and who are at risk of becoming dependent in I-ADL and/or P-ADL. The Housing Enabler was used to define environmental barriers (Iwarsson & Slaug, 2010). The large-scale barrier removal policy targets four specific barriers, with an expected high impact on P-ADL/I-ADL dependence that will be removed in both one-family houses and apartments. The barriers were selected based on four criteria: (1) the barrier should be located in the indoor environment, (2) it should affect several functional limitations, (3) have a prevalence of 0.50 or higher, and (4) have a severity rate of three or above on a scale from 0 (lowest severity) to 4 (highest

severity). The four high-impact barriers identified for removal were the following: (a) no grab bar at shower/bath and/or toilet; (b) wash-basin placed at a height for use only when standing; (c) toilet 47 cm or lower; and (d) steps/thresholds/differences in level between rooms/floor spaces. It is important to note that this policy focuses on the indoor environment, and therefore, does not address common housing adaptations at the entrance area, such as automatic door openers or ramps.

*Simulation model inputs*

The simulation model inputs for sub-study IV (the simulation study) were drawn from various sources, as displayed in Table 8. The reporting and study design was guided by the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement (Husereau et al., 2022).

**Table 8.** Data sources used in this thesis for simulation model inputs.

| |
|---|
| **1. Population-based functional profiles** |
| • SNAC-B, SNAC-N, SNAC-K (SNAC: The Swedish National Study on Aging and Care in Blekinge (B), Nordanstig (N), and Kungsholmen (K), pooled sample N=5,093) |
| **2. Prevalence of environmental barriers in the ordinary housing stock in Sweden** |
| • Home and Health in the Third Age Study (N=371)<br>• ENABLE-AGE database (N=397)<br>• Home and Health in People Ageing with Parkinson's Disease database (N=255)<br>• Older persons from Hässleholm municipality, living in ordinary housing (N=134)<br>• Simul-Age inventory (N=12) |
| **3. Housing adaptation costs** |
| • Interviews with housing adaptation grant managers<br>• Data we received from two of the five partner municipalities |
| **4. Costs for housing policy interventions** |
| • Open source data such as Swedish Tax Agency, Swedish National Board of Housing, Building, and Planning, Statistics Sweden, and previous published studies |
| **5. Effects of poor accessibility on independence (IADL and ADL)** |
| • SNAC-B, SNAC-N, SNAC-K (pooled sample N=5,093) |

*(1) Population-based functional profiles*

To calculate the population-based functional profiles, extracts from the national longitudinal research database, SNAC baseline and six-year follow-up data were used (Lagergren et al., 2004). That is, SNAC-B (Blekinge) (N=1,402 at baseline), SNAC-K (Kungsholmen) (N=3,363 at baseline), and SNAC-N (Nordandstig) (N=766 at baseline). We compiled the variables on socio-economics, demographics, housing, functional limitations, and ADL in a homogenous data set to ensure consistency across all data sources. We excluded participants living in special

housing (n=441), which resulted in a final sample size of N=5,093 participants. For sample characteristics at baseline, see Table 9. To capture functional limitations/dependence on mobility devices, seven variables were selected from the SNAC datasets and harmonized to be comparable to seven of the items used in the Housing Enabler (HE) instrument (Iwarsson & Slaug, 2001; Iwarsson, Haak & Slaug, 2012) (see Table 10). The Housing Enabler is an established instrument that consists of an assessment of 14 items of functional limitations and dependence on mobility devices among individuals or groups, and 161 items focusing on the environmental barriers in the indoor and immediate outdoor environment. Physical environmental barriers and functional limitations are combined to calculate a measure of housing accessibility problems (Iwarsson & Slaug, 2001; Iwarsson & Slaug, 2010).

**Table 9.** SNAC* pooled sample characteristics at baseline.

| Characteristic | Total (N=5,093) | Missing, n (%) |
|---|---|---|
| **Sex, women (%)** | 3,073 (60.3) | 1 (0.02) |
| **Age, mean (min-max)** | 74.3 (60.0-104.6) | 47 (0.8) |
| **Education, n (%)** | | 187 (3.7) |
| Elementary school | 1,616 (31.7) | |
| High school | 2,206 (43.3) | |
| University | 1,084 (21.3) | |
| **Housing type, n (%)** | | 453 (8.9) |
| Apartment | 3,717 (73.0) | |
| One-family house | 923 (18.1) | |
| **Functional limitations, n (%)** | | |
| Cognitive limitation | 308 (7.8) | 146 (2.9) |
| Visual impairment | 255 (5.1) | 90 (1.8) |
| Poor balance | 954 (19.5) | 195 (3.8) |
| Limitations of stamina | 2,083 (45.6) | 523 (10.3) |
| Reduced fine motor skills | 1,406 (28.8) | 205 (4.0) |
| Reduced lower extremity function | 931 (18.7) | 127 (2.5) |
| Dependence on walking aids | 980 (20.9) | 200 (3.9) |
| **Independent in I-ADL** | | |
| Cooking | 4,578 (89.9) | 72 (1.4) |
| Doing the laundry | 4,268 (83.8) | 75 (1.5) |
| Cleaning | 4,555 (89.4) | 73 (1.4) |
| **Independent in P-ADL** | | |
| Using the toilet | 4,935 (96.9) | 64 (1.3) |
| Getting up and going to bed | 4,935 (96.9) | 63 (1.2) |
| Bathing/showering | 4,673 (91.8) | 65 (1.3) |

**The Swedish National Study on Aging and Care in Blekinge, Nordanstig, and Kungsholmen.*

**Table 10.** Functional limitations and corresponding proxies in SNAC datasets.

| Functional limitations according to the Housing Enabler | Proxies for functional limitations according to the SNAC datasets |
|---|---|
| **Cognitive impairment** | Do you feel your memory has become worse? |
| **Visual impairment** | Can you, without any trouble, read normal newspaper/TV text? |
| **Poor balance** | Can you pick up items from the floor? |
| **Limitations of stamina** | Can you run a shorter distance if you are in a hurry/ can you run 50 metres? (level of difficulty) |
| **Reduced fine motor skills** | Can you open jars with lids? |
| **Reduced lower extremity function** | Can you walk stairs? |
| **Dependency on mobility devices** | Do use any walking aids (cane, walker)? |

*(2) Prevalence of environmental barriers in the ordinary Swedish housing stock*

To estimate the prevalence of environmental barriers in the ordinary Swedish housing stock within our sample of the pooled SNAC dataset, we implemented the following procedure. Given that the SNAC sample did not include Housing Enabler (HE) data, we first turned to research databases on housing barriers from ordinary Swedish dwellings, which had been collected in several previous projects utilizing the HE assessment. This approach allowed us to create a more realistic representation of environmental barriers in our sample. We applied, inter alia, data from an inventory with the HE of 12 dwellings in two of the partner municipalities, that is, Eslöv and Örebro. Initially, 50 dwellings in the five municipalities were aimed for, but due to the COVID-19 pandemic restrictions, 12 dwellings were assessed. We strived for dwellings that represented the housing stock of the partner municipalities and collected data from apartments and single-family houses. Data on one item which covers "Insufficient maneuvering surfaces in relation to furniture/movable furnishings" was not collected, since we assessed vacant dwellings during the pandemic. Furthermore baseline data was used from the longitudinal study "Home and Health in People with Parkinson's Disease database" (N=255) that investigates environmental barriers and housing accessibility for people with Parkinson's Disease in three hospitals in Scania, Sweden (Nilsson & Iwarsson, 2013). The cross-sectional study "Home and Health in the Third Age" (N=371) aimed to investigate the living situation and health of older individuals in the Scanian municipalities Eslöv, Malmö, Hässleholm, Osby, and Ystad (Kylén et al., 2014). Furthermore, baseline data on objective aspects of the housing environment from the Swedish sample of the longitudinal study "ENABLE-Age" (N=397) was used (Iwarsson et al., 2007). The participants stemmed from the municipalities of Lund, Helsingborg, and Halmstad and were aged 80-89. Finally, data from a study on older persons from Hässleholm municipality in southern Sweden (N=134), with participants aged 75-84 (Iwarsson & Isacsson, 1996) was included. Data from all these sources were pooled together, and the prevalence of

barriers depending on the type of area (urban or rural) and type of housing (one-family or multi-dwelling block) was estimated. The included datasets used for this study involved a variety of housing types, areas, and building periods, which earlier research has shown to be representative of the ordinary Swedish housing stock (Granbom et al., 2016; Slaug, Granbom & Iwarsson, 2024). The prevalence of each housing barrier was calculated based on housing type (apartment or single-family house) and area (rural or urban).

To estimate the prevalence of barriers in the current study's pooled sample, an algorithm was developed. This algorithm generated a random number between 0 and 1 for each potential barrier in the sample. If the number was lower than the known occurrence rate for that barrier, it was marked as "present"; otherwise, it was marked as "absent". This method was applied to all 5,093 observations in the pooled SNAC sample. The resulting occurrences closely approximate the overall estimated prevalence of environmental barriers in the ordinary Swedish housing stock, while maintaining a realistic variation for each barrier. In addition to the algorithm-based approach, we further refined the barrier prevalence data for each individual case in our pooled sample. This refinement was based on four specific yes/no questions about housing accessibility from the SNAC questionnaire. These questions addressed: (1) handicap accessible indoors, (2) wheelchair accessible entrance, (3) mobility problem accessible entrance, (4) light mobility problem accessible entrance. For each of these questions, if the participant responded with "yes" (indicating that the housing features in question were accessible), the corresponding barriers were set to absent. To calculate the prevalence of environmental barriers, SAS version 9.4 (SAS, 2023) was used.

*(3) Housing adaptation costs*

Data from individual interviews with housing adaptation grant managers and cost calculations of different housing adaptation measures were used (Heller et al., 2022) to calculate the housing adaptation costs.

*(4) Costs for housing policy interventions*

Open source data and data from a previous study was also applied (Swedish Tax Agency, 2023; Swedish National Board of Housing, Building, and Planning, 2023; Statistics Sweden 2023; Jutkowitz et al. 2012) to calculate the costs for housing policy interventions per individual. A comprehensive overview of the initial and weighted costs associated with the simulated policy scenarios is presented in Tables 11 and 12. Various cost components were included in the analysis, such as salaries for occupational therapy (OT) personnel, material for home visits, travel expenses, and the costs for the housing adaptations for each applied policy. For both the home visit with preventive barrier removal policy and the large-scale barrier removal policy, we weighted the costs for barrier removal based on their prevalence in the ordinary Swedish housing stock. The prevalences for barriers targeted by the home

visit with preventive barrier removal policy were: 58% high thresholds, 59% lack of grab bars, 26% high-kerb shower stalls, and 39% bathtub installed instead of a shower. Regarding the large-scale barrier removal policy, the prevalence rates of the targeted barriers in the Swedish housing stock were as follows: steps/thresholds/differences in level between rooms/floor spaces (more than 15 mm), 58%; no grab bar at shower/bath and/or toilet: 59%; toilet 47 cm or lower: 72%; wash-basin placed at a height for use only when standing: 95%. To provide a comprehensive overview, those prevalences were then related to the associated housing adaptation costs. The cost estimation was carried out in a customized Excel table.

**Table 11.** Initial costs for the barriers to be removed.

| Policy and barrier description | Initial costs (SEK) |
|---|---|
| **Initial costs for the four most commonly addressed barriers in the home visit with preventive barrier removal policy** (Swedish National Board of Housing, Building and Planning, 2023a; costs from 2023 provided by one of the partner municipalities) | |
| Removing thresholds | 1,861 |
| Installation of grab bars | 1,861 |
| Replacing high-kerb shower stalls with level-entry or low-threshold designs | 40,000 |
| Installation of shower space, where a bathtub is installed | 7,500 |
| **Initial costs for four high impact barriers according to the HE in the large-scale barrier removal policy** (Iwarsson & Slaug, 2001; costs from 2023 provided by one of the partner municipalities) | |
| Steps/thresholds/differences in level between rooms/floor spaces (more than 15 mm) | 1,861 |
| No grab bar at shower/bath and/or toilet | 1,861 |
| Wash-basin placed at a height for use only when standing | 3,000 |
| Toilet 47 cm or lower. Including seat | 7,500 |

**Table 12.** Comprehensive cost overview of simulated policy scenarios per individual.

| **Care-as-usual policy** | |
|---|---|
| Cost components | Costs in SEK |
| • Salaries for OT personnel conducting preventive home visits (Statistics Sweden, 2023) | 307 |
| • Material for home visits (Jutkowitz et al. 2012) | 32 |
| • Travel expenses (Swedish Tax Agency, 2023) | 36 |
| • Average costs for housing adaptations on a national level (Swedish National Board of Housing, Building and Planning, 2023) | 17,638 |
| *Total costs* | *18,013.00* |
| **Home visit with preventive barrier removal policy** | |
| Cost components | Costs in SEK |
| • Salaries for OT personnel conducting preventive home visits (Statistics Sweden, 2023) | 102 |
| • Training for OT personnel (Statistics Sweden, 2023) | 102 |
| • Material for home visits (Jutkowitz et al. 2012) | 32 |
| • Travel expenses (Swedish Tax Agency, 2023) | 36 |
| • Weighted costs according to utilization rates of the four most commonly addressed barriers (Swedish National Board of Housing, Building and Planning, 2023) | |
| o Removing thresholds | 1,076.03 |
| o Installation of grab bars | 1,107.48 |
| o Replacing high-kerb shower stalls with level-entry or low-threshold designs | 10,296 |
| o Installation of shower space, where a bathtub is installed | 2,910 |
| *Total costs* | *15,661.51* |
| **Large-scale barrier removal policy** | |
| Cost components | Costs in SEK |
| • Weighted costs for four high impact barriers according to the HE (Iwarsson & Slaug, 2001; costs from 2023 provided by one of the partner municipalities) | |
| o Steps/thresholds/differences in level between rooms/floor spaces (more than 15 mm) | 1,076.03 |
| o No grab bar at shower/bath and/or toilet | 1,107.48 |
| o Wash-basin placed at a height for use only when standing | 2,845.20 |
| o Toilet 47 cm or lower. Including seat | 5,388.00 |
| *Total costs* | *10,416.71* |

*Abbreviations: HE= Housing Enabler; OT=*Occupational *Therapist.*

### *(5) Effects of poor accessibility on independence in ADL*

Finally, to calculate the (5) effects of poor accessibility on independence in ADL, extracts from the national longitudinal research database SNAC have been applied (Lagergren et al., 2004). In our study, we focused on specific I-ADLs and P-ADLs.

The I-ADLs examined included cooking, doing laundry, and cleaning, while the P-ADLs comprised using the toilet, getting up and going to bed, and bathing/showering. These particular activities were selected based on data availability and their significant influence on an individual's ability to live independently.

# Data analysis

The data analysis was conducted in line with the structure of the EBPHF (Brownson, Fielding, & Maylahn, 2009) and included the following analysis steps:

- Analysis of community input and quantifying the issue: the policy study (sub-study II).
- Analysis to determine what is known through scientific literature: the literature review (sub-study III).
- Analysis to develop and prioritize program and policy options: (the simulation study (sub-study IV).

## Community input and quantifying of the issue

To analyse the community input received through the data from the individual interviews, research circle, and policy documents in the policy study (sub-study II), and to quantify the issue, content analysis (Mayring, 2014) was used. An inductive approach was deemed appropriate since we wanted to explore new patterns and relationships in the data. NVivo software (version 12) (NVivo, 2023) was used to organize and structure the data as well as to facilitate the analytical procedure.

In a first step, the **individual interviews** were analysed using the inductive category procedure, described as a content analysis method by Mayring (2014). Inductive category formation aims to preserve the systematic procedure of content analysis and mainly considers material that is relevant to the research question. However, Mayring states that it is not a standardized instrument and therefore needs to be adjusted according to the individual material and aim. The systematic analysis is based on a so-called "procedural model", that is, the definition of the individual analysis steps are pre-defined (Mayring, 2014). We followed a nine-step procedure on how to systematically approach the material (see Figure 4). Due to the scarcity of previous studies focusing on our aim, an inductive approach was chosen to conduct the analysis. After defining a concrete research question, the transcripts of the individual interviews were read independently by the author of this thesis (CL) and Björn Slaug (BS), followed by coding relevant words, sentences, or sections. In a next step, CL and BS worked through 10% of the material line by line and created

categories individually from each other. Lisa Ekstam (LE) and Maria Haak (MH) then revised those categories in a strong inter-coder agreement check. Any disagreements were solved through consensus discussions between CL, BS, LE and MH. The inter-coder agreement check aims to improve reproducibility by increasing the independence from the content analysis by the coder (Mayring, 2014). Therefore, a percentage of the observed agreements on the categories was divided by the total amount of categories, resulting in a 59% agreement rate. Fifty percent of the remaining material was then coded by CL using the categories the researchers (CL, BS, MH, and LE) had agreed on, and were subject to a light inter-coder agreement check. The light test of inter-coder agreement aims to confirm the analysis of the first coder and entails the insight of the other coders (BS, MH, and LE) into the entire material and coding. After consensus was reached, CL proceeded with the analysis of the 50% of the remaining transcripts and another light inter-coder agreement check was conducted with all co-authors (BS, MH, LE, and Steven Schmidt (SS)) to validate this step of the analysis. In a final step, CL created themes and checked for patterns in the coded material.

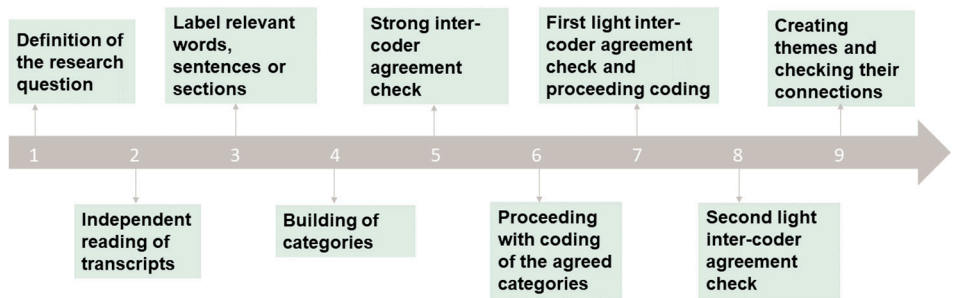


**Figure 4.** Procedural model used for the inductive category formation (adapted from Mayring, 2014).

In a second step, the **policy documents and the priority list stemming from the research circle** were analysed separately by CL using the same method as in the individual interviews. The categories and codes created after the analysis were then subject to a light inter-coder agreement check by all co-authors but mainly confirmed the data extracted from the individual interviews.

## What is known through scientific literature

To extract data from the systematic literature review (sub-study III), a customized Microsoft Excel table was employed. An inductive approach with a focus on narrative synthesis was chosen to merge the heterogeneous findings from the set of included studies and to explore relationships within the data. Narrative synthesis was chosen because it can identify and synthesize data sources with high

heterogeneity. It was deemed appropriate to make the findings comprehensive and elucidate reasons for the strength or lack of strength of the evidence on the relationships between housing and health (Popay et al., 2006). To analyse the data, CL reviewed the included studies and outlined a synthesis draft for how the data could be presented by regrouping the studies based on the exposure, that is, the measurement of physical housing characteristics, and the study designs. The synthesis was then, discussed and agreed on by BS and MH.

## Developing, prioritizing, and evaluating program and policy options

*Economic evaluation by conducting a cost-effectiveness analysis*

Through economic evaluation, a treatment, policy or program will be compared to one or more alternatives (Brent, 2014). Economic evaluation has been used widely in health economics and evidence-based practice (Edlin et al., 2015; Brownson, Fielding, & Maylahn, 2009). Especially in a field such as public health, where resources such as time or money are scarce, it becomes increaslingly more important to identify relevant intervention alternatives based on organized considerations (Drummond et al., 2015). Furthermore, one of the fundamental objectives of public health is to address the needs of the entire population through targeted interventions or comprehensive policies. This approach aligns closely with the purpose of cost-benefit analysis, i.e., the aggregation of benefits to the whole population (Chapman, Preval & Howden-Chapman, 2017). The evaluation of health policies is also considered important in the evidence-based public health framework (EBPHF). The tracking of outcomes and the improvements or adjustments of public health policies and interventions are some particular examples of competencies for the implementation of public health policies (Brownson, Fielding, & Maylahn, 2009). In economic evaluations, three types of analyses are being used that differ in their measurement of expected consequences. These are cost-utility analysis, cost-effectiveness analysis, and cost-benefit analysis (Table 13) (Drummond et al., 2015). In this thesis, cost-benefit analysis was used, since the monetary evaluation of two new housing policies, i.e., a home visit with preventive barrier removal policy, and a large-scale barrier removal policy were compared to a care-as-usual policy. Furthermore, public health policy decisions are limited by budgets; therefore, it is important to provide tools, such as the cost-benefit analysis, to identify how resources should be allocated. Therefore, Markov models have been used to calculate cost-related long-term prognoses. Markov models are particularly useful for calculating long-term health effects, and when there is a large number of potential health effects (Edlin et al., 2015). Since we aimed for long-term projections of 20 years into the future and the transition from the ADL independence to dependence state in a recurring manner, Markov models were deemed appropriate.

**Table 13.** Types of economic evaluation analyses (adapted from Drummond et al., 2015).

| Type of analysis | Measurement of expected consequences |
|---|---|
| **Cost-utility analysis** | Healthy years (quality-adjusted life years) |
| **Cost-effectiveness analysis** | Natural units such as gained life-years, reduction of weight in kg, disability days saved |
| **Cost-benefit analysis** | Monetary units |

*A three-step analysis procedure toward Markov models*

To conduct the Markov models, a three-step procedure (see Table 14) was followed that takes into account the analysis steps of the decision model (see Figure 5). The decision model, derived from the theoretical model (see Figure 2 under the section *Analytical model used in this thesis*), and was developed to investigate changes in ADL dependence and independence in terms of costs for different health outcomes. These outcomes include living independently, receiving home health services, living in special housing, and mortality (death) over time. Living independently in this context means "living alone, with family, friends or partner in one's own or rented apartment without any regular professional assistance" (Ahlqvist, Nyfors & Suhonen, 2015). Receiving home health services entails assistance with household tasks such as going shopping or cleaning, etc. or/and assistance with daily personal care such as bathing/showering, eating, etc. (Schön, Lagergren & Kåreholt, 2015). Living in special housing refers to the Swedish term "särksilt boende". Here we refer to accommodations for people aged 65 and older, that are in need of additional assistance for instance, nursing homes or housing specifically designed for people with dementia (Swedish National Board of Health and Welfare, 2016). Finally, the death state (mortality) entails the number of deaths in a specific population over a given period of time (National Institute of Health, 2023).

**Table 14.** Overview of the three-step procedure for developing Markov models.

| |
|---|
| 1. Calculation of odds ratio of becoming dependent |
| 2. Calculation of event rates of poor accessibility on independence |
| 3. Integration of the event rates into TreeAge for population-level simulation |

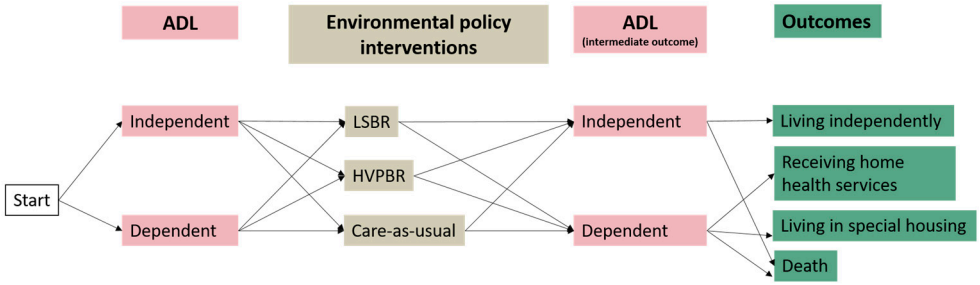


**Figure 5.** Decision model.
*Abbreviations: ADL=Activities of Daily Living; LSBR=Large-scale barrier removal policy; HVPBR= Home visit with preventive barrier removal policy.*

*1. Calculation of odds ratio of becoming dependent*

In the first step, the odds ratio (OR) of becoming dependent in relation to housing accessibility problems was determined. To assess those housing accessilbity issues, the HE score (based on the HE instrument) was utilized. (Iwarsson, Haak & Slaug, 2012). To calculate the HE score, data on environmental barriers in the housing environment and data on functional limitations among individuals is used. Each problematic combination is assigned to severity levels ranging from 1 to 4 (with 1 indicating a potential problem, 2 indicating a problem, 3 indicating a severe problem, and 4 indicating an impossible problem), and these levels are summed to produce the HE score. This score serves to predict the extent of accessibility issues in a specific case; a higher HE score indicates more housing accessibility problems. In this study, we focused on barrier items from the indoor environment (87 out of a total of 161) and examined seven functional limitations/dependence on mobility devices (out of 14). For an overview of the functional limitations/dependence on mobility devices according to the HE and the corresponding proxies used from the SNAC please see Table 10 in section *"Population-based functional profiles"*. We then performed a logistic regression analysis, controlling for factors such as age, sex, education, and baseline HE score to account for changes in functional ability over a six-year period. To estimate the odds of becoming dependent within a year, we divided the calculated odds by 6, yielding a more precise representation of the annual odds of becoming dependent.

*2. Calculation of event rates of poor accessibility on independence*

In the second step, the OR from step 1 and the HE score were used to calculate the event rate of becoming dependent in at least one IADL for each policy. The simulation model included annual transition probabilities, also referred to as event rates, between specified health states (see Table 15). These transition probabilities represent the likelihood of individuals moving from one health state to another. For the care-as-usual policy, the event rate was based on actual data from year one,

which was 3.479%. The differences in event rates between the home visit with preventive barrier removal and the large-scale barrier removal policy were determined by point reduction after re-calculating the HE score with removal of selected barriers for each respective policy. This resulted in an event rate of becoming dependent of 3.424% for the large-scale barrier removal policy and 3.436% for the home visit with preventive barrier removal policy. We then calculated event rates for the health outcomes, including receiving home health services, living in special housing, and death. Due to limited data on transition probabilities from home health services to special housing, we made several assumptions. We presumed that vacancies in special housing would be filled promptly after resident deaths, given that municipalities maintain waiting lists and the average wait time for placement in special housing is on average 63 days (Kolada, 2024). Furthermore, we assumed, that individuals currently receiving home health services would be the most likely candidates to transition to special housing. Therefore, to estimate the annual transition rate, we divided the annual number of deaths among individuals living in special housing by the total number of individuals receiving home health services. This calculation yielded an annual transition probability of 10.08% for those moving from home health services to the special housing state. The event rate for death was estimated using the most recent population statistics on mortality across different age groups represented in the simulation (Statistics Sweden, 2023a) and were as follows: 1.43% for individuals living independently, 13.16% for those receiving home health services, and 22.89% for those living in special housing. All event rates were calculated using a customized Excel file that included key health states as outlined in the decision model (see Figure 5 in section "*A three-step analysis procedure toward Markov models"*).

**Table 15.** Annual probabilities of transitioning between specified health states.

| Description of health states | Annual transition probabilities between health states (%) |
|---|---|
| **Transition to death while living independently** | 1.43 |
| **Transition to death while receiving home services** | 13.16 |
| **Transition to death while living in special housing** | 22.89 |
| **Transition from receiving home services to special housing** | 10.08 |
| **Transition from independent living to care-as-usual policy** | 3.47 |
| **Transition from independent living to receiving home service in large-scale barrier removal policy** | 3.42 |
| **Transition from independent living to home services in home visit with preventive barrier removal policy** | 3.43 |

3. *Integration of the event rates into TreeAge for population-level simulation*

In a third and final step, the Markov models for population-level simulation were conducted. The cost estimates as outlined in Table 12, as well as the effect sizes, calculated in step 2, were added to TreeAge Pro software (Version 2024) (TreeAge, 2024). By the use of Markov models, we followed the cohorts over a specific time period of 20 years allocated to the different interventions in the so-called cycles. A Markov model entails specific states, that is, the basic structure of the model where the individuals are allocated (Drummond et al., 2015). In our study, the Swedish population aged 65 or older, was proportionally distributed at start (time 0) across three states: living independently, receiving home care services, and living in special housing. Simulated cohorts began in the living independently state and progressed for each housing policy to the various health states (receiving home health services, living in special housing, or death) over a 20-year cycle length.

# Ethical considerations

To follow ethical principles for medical research involving humans, the Helsinki Declaration and current national legislation and policies have been considered in all four sub-studies included in this thesis (World Medical Association, 2022). The study protocol (sub-study I) and the systematic review (sub-study III) didn't make use of any sensitive data, therefore, there was no need for an ethical review according to Swedish law (Swedish Parliament, 2003:460). Both the policy study (sub-study II; Dnr 2020-01643) and the simulation study (sub-study IV; Dnr 2020-05871) were approved by the Swedish Ethical Review Authority.

## Informed consent

Participation in the study was voluntary and the participants gave their informed consent prior to the interviews (see Appendix I). The letter of consent was formulated in a way that the interviewees could understand the formulation. Furthermore, participants were given the opportunity to make contact at any given time if the content of the informed consent was unclear. Before conducting and recording the interviews and the research circle we informed the interviewees verbally that they have the right to drop out at any given point.

## Risks and benefits

The studies conducted in this thesis were considered low-risk as they did not involve any risk of injury or discomfort for the participants, nor were they linked to any municipal or regional support, care, or medical care activities. However, in the

policy-study (sub-study II), interviews and a research circle were conducted to gather information about how the municipality addresses housing accessibility. This included asking participants about the knowledge of politicians in making informed decisions regarding housing accessibility, which can be considered as political opinions and sensitive personal data. Other sensitive personal data such as age, sex, and length of employment were also collected. Furthermore, the interviews were recorded, which might touch on the ethical principle of personal integrity and personal data. The simulation study (sub-study IV) retrieved data from the National E-Infrastructure for Aging Research (NEAR) that coordinates existing databases on population-based longitudinal studies on ageing and health in Sweden. Secondary analysis of already collected data was conducted and retrieved from the Swedish National study on Aging and Care in Blekinge (B), Kungsholmen (K), and Nordanstig (N). Other data such as, from the assessment with the Housing Enabler (Iwarsson & Slaug, 2010) of vacant dwellings in two of the five municipalities in the "Simul-Age" project (Schmidt et al., 2022); "Home and Health in the Third Age" (Kylén et al., 2014.); "ENABLE-Age" (Iwarsson et al., 2007), "Home and Health in People Ageing with Parkinson's Disease database" (Nilsson & Iwarsson, 2013); and "Older persons from Hässleholm municipality, living in ordinary housing" (Iwarsson & Isacsson, 1996) were also considered as low risk. The retrieved data could not later be linked to the participating individuals. Participation in the sub-studies may include both low risks and benefits for the participants. The direct benefits for each individual participant were relatively low. However, in the long-term, the findings of the studies could have a positive impact on older adults being able to manage their lives actively and independently, and thereby increase the probability of ageing in their own homes.

## Confidentiality

The participants of sub-study II were informed a priori about the collection of personal data within the interviews and the research circle. With the letter of consent *(see Appendix I)*, the participants were informed that they had the right to drop out at any given point without giving any reason. Before we recorded the interviews, oral information about the personal data collection was given. To increase the personal data safety for the interview and research circle data, any personal identifiers in the transcripts were removed so that the results could not be linked to any individual person. To increase the overall data protection safety, the data from all studies included were handled in accordance with the EU Data Protection Regulation (Article 6 2017/18:298), General Data Protection Regulation (GDPR). To protect data against unauthorized access the data were stored on a platform with strong encryption and were only accessible after two-factor authentication and selective access control by the involved researchers.

# Results

The presentation of the results is conducted in line with the EBPHF (Brownson, Fielding, & Maylahn, 2009), that is:

- Community input and quantifying the issue: the policy study (sub-study II).
- Determining what is known through scientific literature: the literature review (sub-study III).
- Developing and prioritizing program and policy options: the policy study (sub-study II).
- Evaluation of the policies: the simulation study (sub-study IV).

Sub-study I, the study protocol, developed a concise statement of the issues that provides the basis for a policy-setting process. Furthermore, it outlined the preparatory steps for the development of simulation models and served as a guide for the remaining three sub-studies; therefore, it will not be taken up individually in the results section.

## Community input and quantifying the issue

In the policy-study (sub-study II), community input and quantifying the issue according to the EBPHF (Brownson, Fielding, & Maylahn, 2009) was aimed for. We explored the municipalities' current and future housing accessibility policies and what priorities they consider for the future to improve housing accessibility for the population ageing in place. Furthermore, challenges to applying a multisectoral policy approach were includd in the content of the community input and the identification of the issue.

### Challenges to applying a multisectoral policy approach

In the interviews, the key actors mentioned four levels that challenged a multisectoral approach to address housing accessibility as suggested by Dahlgren and Whitehead (1991), that is, the *legal, organizational, socio-demographic, and political levels* (see Figure 6). All four levels touched on the four policy levels

within the Rainbow model on a micro, meso, and macro level; however, the collaboration within those policy levels was lacking (see Table 16).

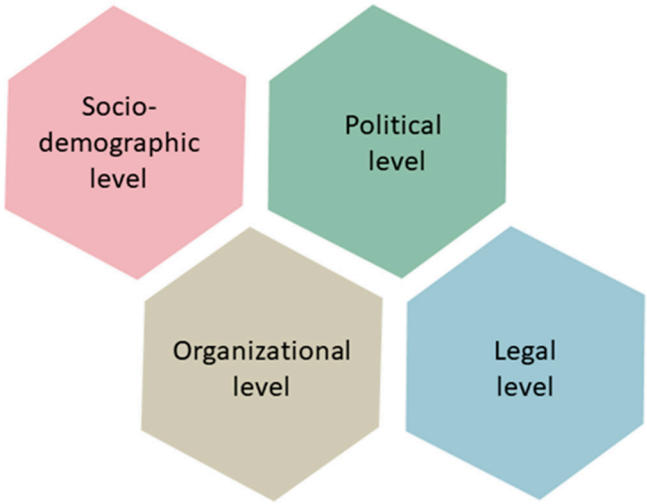


**Figure 6.** Policy levels that challenged a multisectoral approach.

**Table 16.** Levels of policy action and policy settings (Dahlgren & Whitehead, 1991; Harrington, Marshall & Müller, 2006).

| Levels of policy action | Policy settings |
|---|---|
| **First policy level (macro level)** | National and international level |
| **Second policy level (macro-meso level)** | National, regional, and local level |
| **Third policy level (meso level)** | Community and group level |
| **Fourth policy level (micro level)** | Individuals |

The *legal level* created challenges on the meso and macro levels for accessibility improvements. The participants in the interviews acknowledged that, due to limited legal leeway (macro level), municipalities (meso level) had little room to initiate renovations that could increase housing accessibility for the older population among private housing companies (meso level). The *organizational level* within the municipality had a significant impact on accessibility. For instance, there were sometimes conflicts between the micro- and meso perspectives on accessibility. That is, a narrow and more individualistic approach would be beneficial to solve accessibility issues for specific individuals in the municipality, but the holistic view of the administration didn't give any leeway to make decisions on the micro level. The *sociodemographic level* (macro level) challenged the municipalities' current

and future work regarding housing accessibility. The increasing number of older adults in need of accessible dwellings that would fit their needs is a frequent example mentioned in the individual interviews. Through the higher share of older adults, the spatial planning, housing supply, and adaptation of the current housing stock (macro-meso level) to make it more accessible were sometimes hard for the municipalities to predict. Finally, the *political level* (macro and macro-meso level) affected housing accessibility policies according to the participants. The political decisions on housing accessibility policies especially were often based on educated guesses rather than on evidence-based information. In conclusion, the different policy levels have their individual focus and diverse aims on housing accessibility; however, a collaborative and multisectoral approach between those levels seems to be lacking.

## Current and future housing accessibility policies

Through the interviews and the policy documents, six themes and 14 categories were identified that addressed current and future housing policies ranging from organizational, over economic to legal policies (see Figure 7).

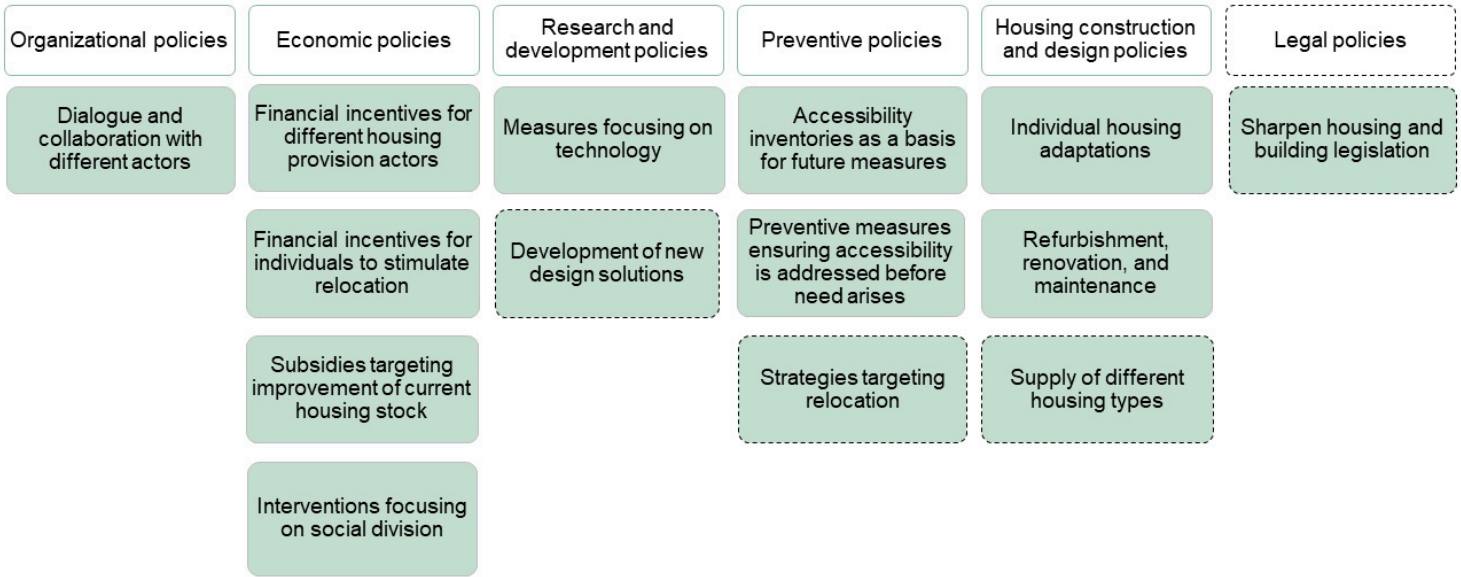


**Figure 7.** Themes and categories after community input of how municipalities address housing accessibility issues.
*Please note: The themes and categories with dashed frames were only discussed in terms of future housing accessibility policies*

*Organizational policies*

The *organizational policies* captured that the *current housing accessibility policies* were addressed by *dialogue and collaboration* between various actors, such as private and municipal housing companies, pensioner organizations, or construction companies. Dialogue and collaboration are related key concepts that involved the exchange of ideas and views in order to reach a certain goal. However, dialogue mainly captured the short-term exchange ideas or views of different actors, while collaboration focused more on cooperation between the municipalities and various actors within long-term projects.

*Economic policies*

The theme of *economic policies* entailed four categories with the richest content. First, *financial incentives for different housing provision actors* were emphasized through the participants and the policy documents. The financial incentives were targeting mainly private and municipal housing companies. The municipalities acknowledged that financial incentives with a focus on housing adaptations might decrease public expenditure, for example home health services, if seniors with functional limitations are able to live in well-adapted homes which fit their needs. Second, *financial incentives for individuals to stimulate relocation* was another category, with a focus on current housing policies mentioned. The municipalities would like to increase the housing market mobility through financial aid targeting older adults with functional limitations. These incentives should reduce so-called "lock-in effects", which are constraints in residential mobility, and in turn, decrease the amount of people with functional limitations staying in inaccessible homes due to low incomes. Third, *subsidies targeting the current housing stock* was mentioned as one mechanism for the municipalities to intervene in the housing market. Currently, no financial aid in the form of subsidies encourages the adjustment, renovation or adaptation of the existing housing stock. In particular, dwellings built before the 1960s show a higher prevalence of environmental barriers in comparison to newly-built housing. Even though housing accessibility in the current housing stock could be improved through renovations or adaptations, it could lead to higher rents and, therefore, be financially less accessible for older adults with lower incomes. Housing companies are therefore reluctant to improve the housing standard to provide inclusive and affordable housing options for older adults with and without functional limitations. If the municipality provides incentives in the form of subsidies to the housing companies in question, it could lead to improved housing accessibility for all citizens. Fourth, *interventions focusing on social division* were considered important measures regarding economic policies and to support housing accessibility. Some examples mentioned were interventions focusing on homeless adults with poor mental health or substance abuse in order to decrease loneliness by providing them with accessible and paid housing.

*Research and development policies*

*Research and development policies* incorporated two themes, of *measures focusing on technology* and *development of new design solutions.* The use of assistive technology and devices were some current examples mentioned as *measures focusing on technology* to improve the housing situation for the older population. Assistive technology was seen as an additional aid to decrease housing accessibility issues, for example through the installation of smart home devices. Furthermore, the *development of new design solutions,* such as new types of lifts that look like a regular staircase but can be adapted to become a lift platform, was a theme considered as important mainly for future policies.

*Preventive policies*

To assess the current housing situation, some of the municipalities conducted *accessibility inventories as a basis for future measures,* either on their own initiative or by private or municipal housing companies. Smaller municipalities expressed economic challenges to carrying out accessibility inventories, even though they saw the beneficial effects of housing accessibility. Other policies with a preventive character mentioned included the *preventive measures that ensure accessibility is addressed before the need arises.* The focus of such policies was on barrier removal to decrease the risk of falls and to enhance housing accessibility. Other current preventive measures focused on social activities to increase participation and information among older people, such as workshops or housing counselling. To support *strategies targeting relocation,* information about relocation, relocation chains, and relocation assistance were some specific examples mentioned by the municipalities targeting future housing accessibility policies. Information about relocation mostly aimed to increase the knowledge about relocation and different relocation aids among older adults on the municipal level to stimulate moving. Relocation chains is a policy strategy used that describes how newly-built and more accessible housing increases the overall relocations in housing stock. Those who choose to move to newly-built housing are often leaving behind a home that in turn becomes available to another household. Relocation assistance was suggested as an incentive for older adults with lower incomes who cannot afford a moving company, to enable them to move to a more accessible home.

*Housing and construction policies*

To address current housing accessibility issues, *individual housing adaptations* through public funding was mentioned as one of the major housing and construction policies. Several housing adaptations such as installing showers instead of bathtubs, stair lifts, removing thresholds, or stove guards, were mentioned as core examples. Housing adaptations were seen as an opportunity to increase social participation and reduce the need for other societal costs by delaying the relocation to care facilities. *Refurbishment, renovations, and maintenance* were mentioned as another current

housing and construction policy. By renovating and adapting existing housing, the housing standard can be improved, which in turn could reduce accessibility issues. It was also seen as a sustainable policy to reduce costs and building materials. To decrease social segregation, *supply of different housing forms* was described as a policy for the future to promote socially mixed and a variety of different housing. Furthermore, to increase the diversity of tenure types, the provision of self-owned family houses, rental, or co-operative apartments, were responses to the wishes of older adults on the municipal level.

*Legal policies*

Legal policies entailed the category of *sharpen housing and building legislation* and mostly addressed future policies. This theme captures the discussions on the challenges of properly addressing housing accessibility. The current law seems to be vague and leaves room for interpretation when it comes to the interchangeable use of the terms accessibility and usability.

# Determining what is known through scientific literature

To determine what is known through scientific literature, according to the EBPHF (Brownson, Fielding, & Maylahn, 2009), a systematic review (sub-study III) was deemed appropriate to synthesize the evidence on the relationships between physical housing characteristics or housing accessibility and different aspects of health among community-living older people (60 years and older).

From database searches and citation searches, 4,217 records were screened by title and abstract, and 123 full-text papers were retrieved. After the full-text screening, 15 papers were included. The overall quality of evidence of the included papers was assessed as very low (see Appendices III and IV). Three themes associated with aspects of health among community-dwelling older adults emerged through the narrative synthesis; those were:

- Interventions by home modifications targeting housing features both at entrances and indoors.
- Non-intervention studies targeting indoor features.
- And non-intervention studies targeting entrance features.

In this thesis, intervention studies refer to studies that addressed interventions by home modifications on different health outcomes, comparing various participant groups. Non-interventions studies in this context measured the effect of indoor or entrance features without group comparisons.

## Interventions by home modifications

Of the 15 included papers, three studies (Mitoku & Shimanouchi, 2014; Szanton et al., 2011; Taylor et al., 2020) examined interventions involving home modifications and assessed the effect on various health outcomes. Including *body functions* (Taylor et al., 2020); *quality of life* (Szanton et al., 2011; Taylor et al., 2020); *P-ADL* (Mitoku & Shimanouchi, 2014; Szanton et al., 2011; Taylor et al., 2020); and *I-ADL* (Szanton et al., 2011).

The first study by Mitoku & Shimanouchi (2014) included follow-ups after one, two, and three years. The longitudinal study compared the health outcomes of participants who had their homes modified and those who did not. Home modifications included eliminating floor height differences, installation of handrails, and changing the floor materials, doors, or sink. The second study focusing on interventions by home modifications was a pilot randomized controlled trial (RCT) by Szanton et al. (2011). The health outcomes of two groups, an intervention group and a control group, were compared after 24 weeks of follow-up. The intervention group received home modifications such as the removal of thresholds and holes in the floor, or adjustments of lighting after a study-specific protocol, while sessions of attention control were given to the control group. Participants in the attention-control group were provided with an equal amount of visits, as those in the intervention group. During those sessions, they engaged in sedentary activities of their choice. In the third study, a RCT, health outcomes were compared between the intervention and control group after six and 12 months of follow-up (Taylor et al., 2020). The intervention group received home modifications based on a home hazards checklist developed by Clemson et al. (1999), while the control group received standard care.

In terms of health outcomes, no statistically significant differences were found regarding *body functions* between the intervention and control group (Taylor et al., 2020). The assessment of *quality of life* showed mixed results. Improvements in quality of life were reported in the intervention group in the study by Szanton et al., (2011) (Cohen's D .48 and .89, respectively); however, no significant differences between the intervention and control group could be found in the RCT (Taylor et al., 2020). Also, the findings of *I-ADL* and *P-ADL* varied between the studies. Both Mitoku & Shimanouchi (2014) and Taylor et al. (2020) found that fewer people decreased in P-ADL, but the results were not statistically significant. The pilot-RCT, however, showed a decrease in P-ADL (Cohen's D .63) and I-ADL (Cohen's D .62) difficulties at follow-up (Szanton et al., 2011). For a simplified summary of the results focusing on interventions by home modifications, see Figure 8.

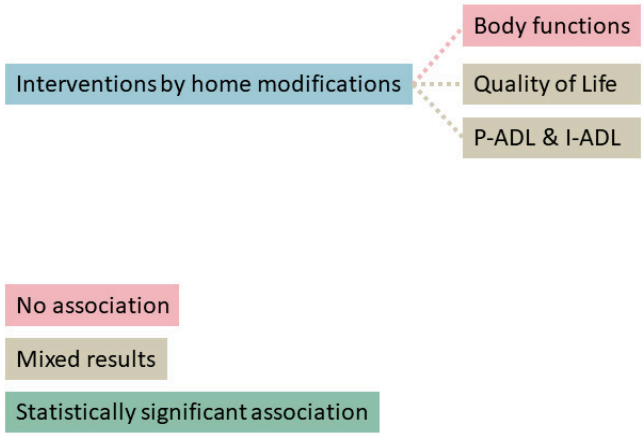


**Figure 8.** Simplified model of the results of interventions by home modifications.
*Please note: The model does not give any information about the direction of the effects.*

## Non-intervention studies targeting indoor features

Eight studies investigated the impact of indoor features (González et al., 2020; Kim et al., 2021; Leung et al., 2018; Nakhodaeezadeh et al., 2017; Slaug et al., 2017; Tomsone et al., 2013; Tsuchiya-Ito et al., 2019; Yang & Sanford, 2011) on health outcomes. Those were, *body functions* (González et al., 2020; Yang & Sanford, 2011)*; quality of life (*González et al., 2020; Nakhodaeezadeh et al., 2017*;* Leung et al., 2018); *life satisfaction* (Kim et al., 2021; Tsuchiya-Ito et al., 2019)*; I-ADL dependency* (Slaug et al., 2017); *social participation* (Leung et al., 2018; Yang & Sanford, 2011); and *self-perceived health* (Tomsone et al., 2013; Tsuchiya-Ito et al., 2019). The majority of the studies had a cross-sectional design (González et al., 2020; Kim et al., 2021; Leung et al., 2018; Nakhodaeezadeh et al., 2017; Tomsone et al., 2013; Tsuchiya-Ito et al., 2019; Yang & Sanford, 2011); only Slaug et al. (2017) conducted a longitudinal study.

In terms of *body functions* and indoor features, both cross-sectional studies found statistically significant associations. Barrier-free dwellings such as slippery floors or stairs were significantly associated with a lower risk of cognitive decline among the participants (OR .95; CI .92 to .96) (González et al., 2020). Another statistically significant association was reported with fewer physical barriers in the home environment and fewer mobility limitations (OR range from .257 to .627; CI not reported) (Yang & Sanford, 2011).

All three cross-sectional studies with a focus on *quality of life* and indoor features. (González et al., 2020; Nakhodaeezadeh et al., 2017*;* Leung et al., 2018) found

positive associations. However, one study also reported a negative impact of indoor features on the overall quality of life (Leung et al., 2018). Positive associations could be found among older adults living in a housing environment that is free of potential hazards, such as limited space, overcrowded furniture, or stairs without handrails and a higher level of quality of life (OR 6.54; CI 1.75 to 24.46) (González et al., 2020). Nakhodaeezadeh et al. (2017) also found positive correlations (Corr coeff 0.279) between a higher quality of life and the lack of deficiencies in several rooms such as the kitchen, hallway, or entrance. Finally, a positive association between indoor features, such as accessible furniture and fixtures, lighting (Est. Furniture and fixtures .092; Est. Lighting .149), and a higher quality of life, was found in the study by Leung et al. (2018). However, they also reported a negative impact of handrails in the sleeping and living room and overall quality of life (Est. Handrails -.125).

Mixed results were found on *life satisfaction* and indoor housing characteristics. Kim et al. (2021) reported significant associations between a higher level of perceived housing accessibility, as well as usability and a higher level of life satisfaction (Est. .22; CI -.015 to .04). However, a lower life satisfaction and inaccessible housing, i.e., the absence of railings or the inability to walk stairs, both among participants with high and with low ADL dependency showed no significant association (Tsuchiya-Ito et al., 2019)

The only longitudinal study was also the only study that investigated the impact of indoor features on *I-ADL* (Slaug et al., 2017) in German and Swedish samples. The I-ADL items captured cooking, shopping, cleaning, and transportation. Older adults living in less accessible housing had a higher risk of becoming dependent in one of the I-ADLs in comparison to older adults that lived in accessible housing (OR range from 1.003 to 1.011 (CI 1.000 to 1.015)). However, no association between accessible housing and cleaning could be found in the German sample.

Among the studies focusing on *social participation* (Leung et al., 2018; Yang & Sanford, 2011) and indoor features, positive associations could be found. Accessible furniture and fixtures (Est. .09), as well as sufficient lighting (Est. .11), were associated with an improvement in social relationships, i.e., social contacts, as investigated by Leung et al. (2018). Self-perceived indoor barriers, such as shower space (OR 29.0), height of the toilet (OR 25.0), and toilet space in the bathroom (OR 46.7), showed an increased risk for low community participation (CI not reported) (Yang & Sanford, 2011).

Finally, the studies that investigated indoor features and *self-perceived health* (Tomsone et al., 2013; Tsuchiya-Ito et al., 2019) showed positive, negative, and no associations. Positive associations could be found between self-perceived health and objectively measured barriers at the entrance among ADL-independent older adults (Latvian sample) (Est .009 (CI .03 to .15), while negative associations were found between self-perceived health and indoor barriers among ADL-dependent older

adults (Swedish sample) (Est -.08 (CI -.14 to -.02) (Tomsone et al., 2013). Tsuchiya-Ito et al. (2019) found no associations between self-reported health and indoor accessibility. For a simplified summary of the results focusing on non-intervention studies targeting indoor features see Figure 9.

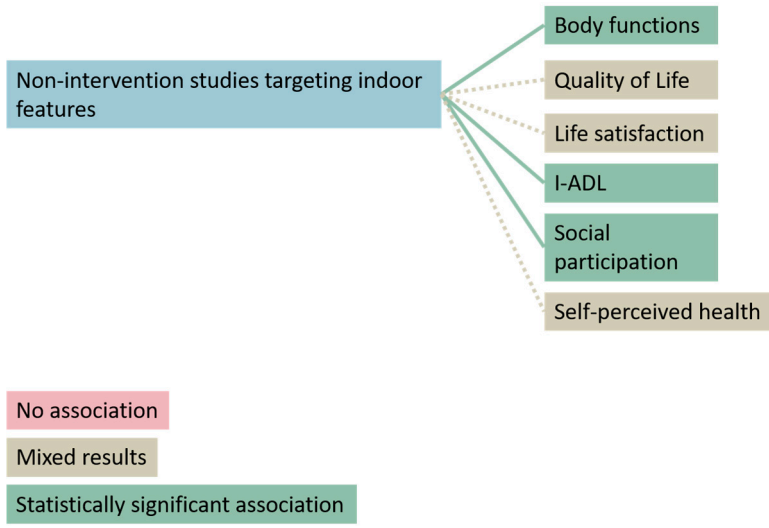


**Figure 9.** Simplified model of the results on non-intervention studies targeting indoor features.
*Please note: The model does not give any information about the direction of the effects.*

## Non-intervention studies targeting entrances

Four of the 15 included studies examined the impact of entrance features on various aspects of health. The studies investigated the effects on *body functions* (Clarke, 2014; García-Esquinas et al., 2016; Pérez-Hernández et al., 2018) and *I-ADL* (García-Esquinas et al., 2016; Pérez-Hernández et al., 2018; Tomioka et al., 2018).

In terms of *body functions,* the studies investigated either the exposure to walk-up buildings, i.e., buildings without access to an elevator, or the walking surface leading to the building, with the presence of ramps or stairs. Two studies had a longitudinal design (Pérez-Hernández et al., 2018; Tomioka et al., 2018), while the remaining were cross-sectional studies (Clarke, 2014; García-Esquinas et al., 2016). No association was found between older adults living in a walk-up building and reduced body functioning (García-Esquinas et al., 2016; Pérez-Hernández et al., 2018). An increased risk of difficulties going outside and stairs at the entrance was found in the study by Clarke (2014) (OR 1.52; CI 1.21 to 1.91).

Among the studies that examined *I-ADL* and entrance features (García-Esquinas et al., 2016; Pérez-Hernández et al., 2018; Tomioka et al., 2018), only the longitudinal

study by Tomioka et al. (2018) showed a statistically significant association between older women living in walk-up buildings and I-ADL decline in comparison to men (OR .72; CI .52 to .99). Neither García-Esquinas et al. (2016) nor Pérez-Hernández et al., (2018) could see any association between living in a walk-up building and I-ADL decline among the participants. For a simplified summary of the results focusing on non-intervention studies targeting entrances see Figure 10.

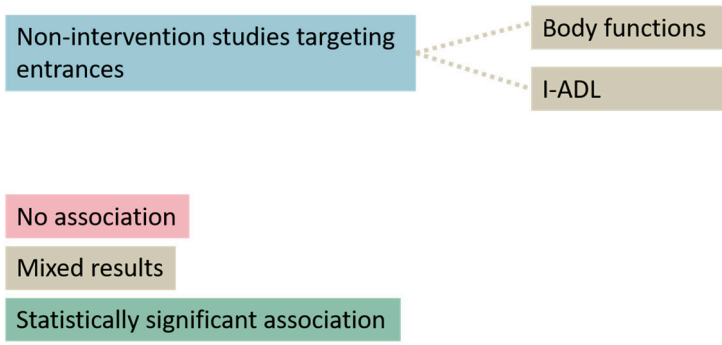


**Figure 10.** Simplified model of the results on non-intervention studies targeting entrances.
*Note: The model does not give any information about the direction of the effects.*

# Developing and prioritizing program and policy options

To identify policy options and set priorities among future policy alternatives according to the EBPHF (Brownson, Fielding, & Maylahn, 2009), the key actors from the municipalities and the senior citizens, together with the participating researchers, developed a list during the research circle of seven policy priorities to address housing accessibility for the future (see Figure 11).

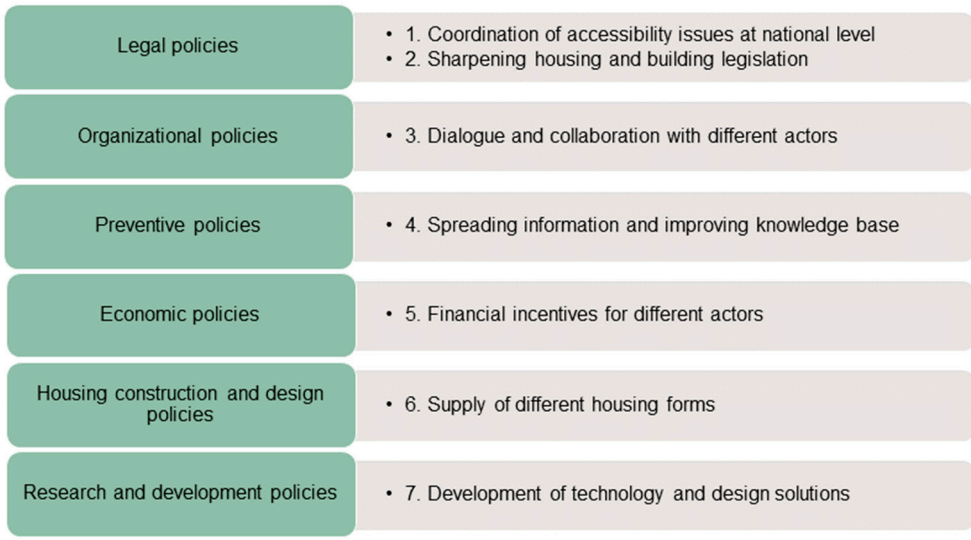


**Figure 11.** Future policy priorities.

*Policy priority 1*

In terms of legal policies, the highest priority was given to *the coordination of accessibility issues at a national level.* The discussions during the research circle captured the need for a consensus view on housing policies. Cross-sectorial collaboration and the implementation of a multisectoral approach across all policy levels are needed to increase accessibility.

*Policy priority 2*

The vagueness of the current legislation regarding the concepts of universal design, accessibility, and usability was discussed by the participants. Therefore, *sharpening housing and building legislation* was the second priority mentioned with a focus on legal policies. The participants also expressed their concerns about the current legislation, which does not sufficiently consider the needs of people with cognitive limitations. Therefore, the current law should be strengthened in order to create a more inclusive environment, both for people with functional and/or cognitive limitations.

*Policy priority 3*

The third policy priority of *dialogue and collaboration with different actors* covered organizational policies. The first policy priority already touched upon dialogue and collaboration on a national level; the third policy priority, however, is instead located on a municipal level. The participants would like to strengthen the dialogue and collaboration between different actors, such as non-profit organizations,

municipal and private housing companies to include different views, perspectives, and expertise.

*Policy priority 4*

The fourth policy priority was given to *information and improving the knowledge base,* and is located within preventive policies. The policy aims to strengthen the knowledge base among individuals, politicians, and public officials. Furthermore, gaining knowledge on the current housing accessibility situation and how it affects other aspects of life, such as social participation, was considered important. To achieve this, individuals should receive specific information about moving chains to increase the value of relocating to a more accessible home. Some other examples mentioned were relocation counselling or apps that could match the current and future needs of the individual with an accessible home. A national information campaign targeting individuals was another example mentioned. The campaign supports the preventive character of the policy and should increase the knowledge base among citizens to relocate to an accessible home before functional limitations appear or increase. The knowledge base should also be strengthened among politicians to make informed decisions regarding housing accessibility, instead of relying on gut feelings or educated guesses.

*Policy priority 5*

*Financial incentives targeting different actors,* such as individuals, private and municipal housing companies, construction companies, or smaller municipalities, were considered as the fifth policy priority. One suggestion was to introduce subsidies for older people with lower incomes who cannot afford to move to a more accessible home and to stimulate relocation. To increase housing accessibility, subsidies for private and municipal housing companies and construction companies were mentioned, to after-install elevators or to stimulate housing adaptations. Furthermore, national aid packages should be provided to smaller municipalities with special socio-demographic circumstances.

*Policy priority 6*

The sixth policy priority emerging through the discussions was the *supply of different housing forms* which is located under housing construction and design policies. The planning and supply of housing that can be used by younger and older generations close to public transportation, culture, and services, such as healthcare operators, was considered important by the participants.

*Policy priority 7*

The participants underlined the need for research and development policies through the *development of technology and design solutions.* In particular, the policies should include technical solutions to support older adults with cognitive limitations

so they can age in place. Preinstalled smart home devices, stove guards, or simple solutions to open heavy entrance and fire protection doors were examples mentioned that would increase the security of older people ageing in place.

# Evaluation of the policies

The EBPHF emphasizes the importance of evaluating policies to track their outcomes and make any necessary adjustments (Brownson, Fielding & Maylahn, 2009; Brownson et al., 2009). Five Swedish municipalities prioritized a range of housing policies, spanning from improving dialogue and collaboration between different actors to preventive policies, as detailed in the policy study (sub-study II). From these identified policy priorities, two specific policies for simulation comparison were selected, these are, home visit with preventive barrier removal and large-scale barrier removal. Both of these policies underwent a cost-benefit analysis in comparison to a care-as-usual policy. We evaluated the cumulative costs, cost trajectories, and the policies' impact on living independently.

## Evaluation of cumulative costs

We compared the two new policies, i.e., the large-scale barrier removal policy and the home visit with preventive barrier removal policy, to the care-as-usual policy. Table 17 presents the cumulative costs (in SEK) per individual over a 20-year span.

**Table 17.** Cumulative costs of the simulated housing policies per individual over a 20-year period.

| Policy | Cumulative costs in SEK per individual after 20 years |
|---|---|
| **Large-scale barrier removal policy** | 14,340,000 |
| **Care-as-usual policy** | 19,005,000 |
| **Home-visit with preventive barrier removal policy** | 19,914,000 |

*Large-scale barrier removal policy*

Among all policy scenarios included in the cost-benefit analysis, the large-scale barrier removal policy emerged as the policy with the lowest total costs of 10,416.71 SEK at the starting point of year 0 (see Table 12). After a 20-year period, the large-scale barrier removal policy maintained the lowest cumulative costs at 14,340,000 SEK per individual, indicating long-term cost benefits among the examined policies as outlined in Table 18.

*Care-as-usual policy*

Care-as-usual showed the highest initial costs at year 0 at 18,013.00 SEK (see Table 12). After 20 years, the cumulative costs were slightly lower than the home visit with preventive barrier removal policy, resulting in 19,005,000 SEK per individual (see Table 18).

*Home visit with preventive barrier removal policy*

The home visit with preventive barrier removal policy demonstrated moderate costs of 15,661.51 SEK at starting point (year 0) as outlined in Table 12. By the end of the 20-year period, however, it totalled the highest cumulative costs of 19,914,000 SEK per individual, in comparison to the other policy scenarios (see Table 18).

## Evaluation of cost trajectories

Initially, from year 0 to five, all three policies demonstrated relatively similar cost trajectories. However, from year five to year 20, the large-scale barrier removal policy outnumbers the care-as-usual and the home visit with preventive barrier removal policy in terms of societal costs. Figure 12 displays the development of societal costs from year 0 to 20 of the home visit with preventive barrier removal, large-scale barrier removal, and care-as-usual policy.

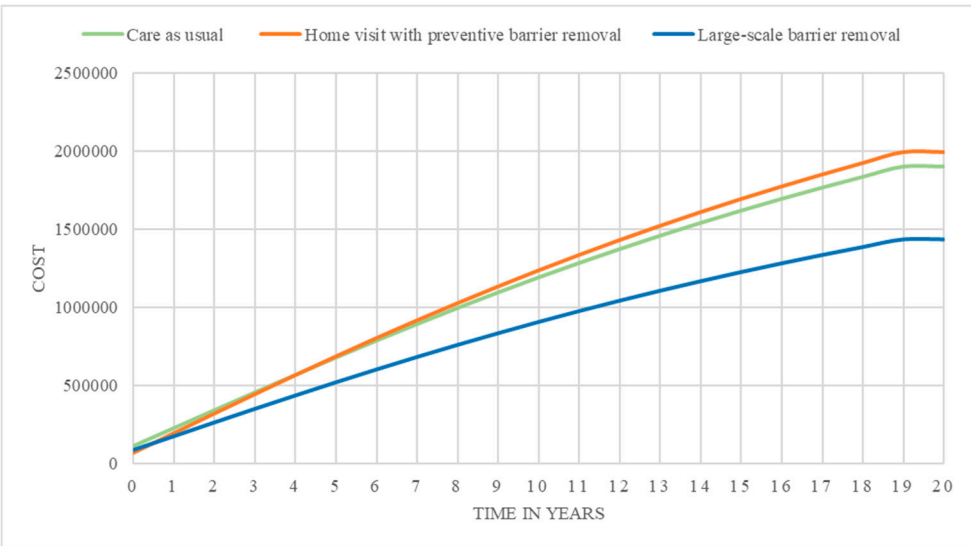


**Figure 12.** Evaluation of cost trajectories of the simulated policies and the use of societal costs over 20 years.

## Evaluation of the impact on living independently

One year after implementation of the new policies there would be an increase of 777 individuals aged 65 and older living independently in the home visit with barrier removal policy, and 150 more individuals in the large-scale barrier removal policy continuing to live independently in comparison to care-as-usual. This positive trend persists and amplifies over time. By year 20, 5,991 more individuals would be enabled to live independently in the home visit with barrier removal policy, and 1,154 more individuals in the large-scale barrier removal policy, compared to the care-as-usual policy. Figure 13 displays the cases that remain to live independently in the large-scale barrier removal and the home visit with preventive barrier removal compared to care-as-usual over a 20-year period.

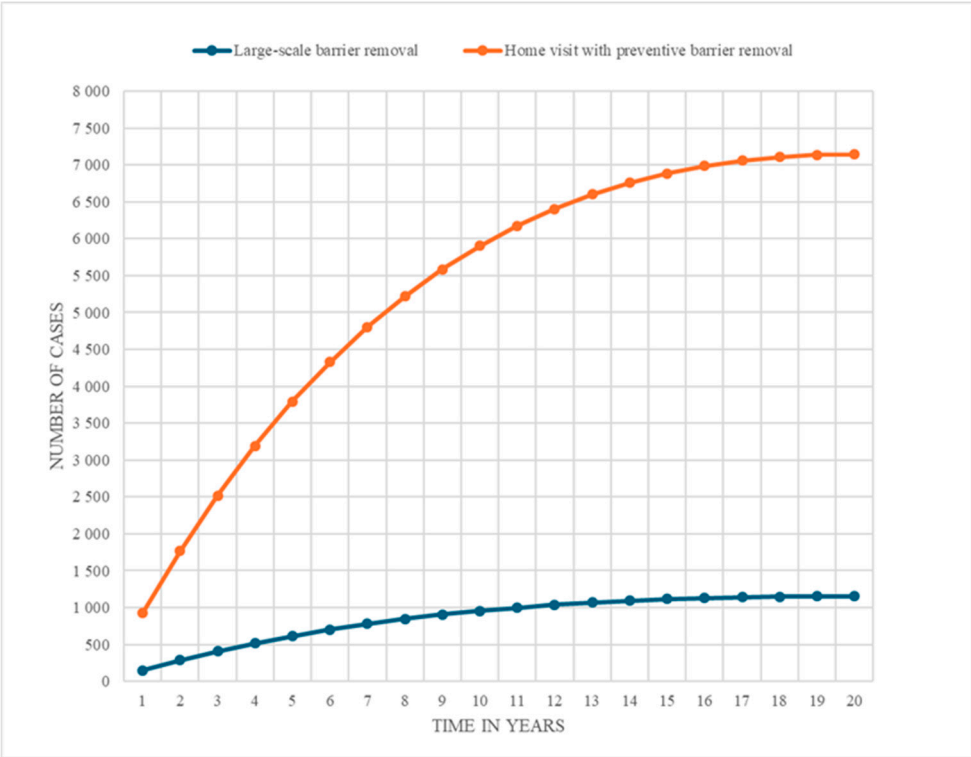


**Figure 13.** Cases remaining to live independently in the large-scale barrier removal and the home visit with preventive barrier removal compared to care-as-usual over 20 years.

# Discussion

This thesis has provided new insights into housing policies and the health of the population ageing in place. This discussion section will begin by presenting a discussion of the results, by linking them to the evidence-based public health framework (EBPHF). The use of the EBPHF has the potential of implementing policy suggestions, and aims to bridge the gap between research and decision-making (Brownson, Fielding & Maylahn, 2009). Following this, there will be a methodological discussion focusing on the strengths and limitations of the study. The following key competencies based on the EBPHF will be discussed: (a) developing a concise statement of the issue, (b) community input and quantifying the issue, (c) determining what is known through scientific literature, (d) developing and prioritizing program and policy options, and (e) evaluation of the policies. It is important to note that the competency of developing an action plan and implementing interventions was not fully addressed in this thesis. While the thesis contributed to some extent to this competency, a comprehensive action plan typically involves several goal-setting strategies at both executive and strategic levels. The scope of this thesis was primarily exploratory, prioritizing the understanding of the current landscape of housing policies rather than executing specific interventions.

## Developing a concise statement of the issue

Developing a concise statement of the issue is an important step in the EBPHF, with the aim to formulate a written statement of a public health issue or policy (Brownson, Fielding, & Maylahn, 2009). In this thesis, the study protocol (sub-study I) contributed to this competency. Brownson et al. (2011) stated that a concise statement of the issue should include the following steps: a description of the problem, potential solutions, data sources, and health-related outcomes.

Following the EBPHF competencies, the problematization was that there is a paucity of studies investigating the long-term potential benefits of different housing policies, which are of high importance for housing provision planning and the health of the population ageing in place. Simulation modelling and more specifically, cost-benefit analysis, has the potential to provide policy-makers with plausible projections long into the future, supporting sustainable and informed decisions that

may contribute to solve the issue. The biggest discrepancy between the study protocol (sub-study I) and the simulation study (sub-study IV) lies in the scope of different data sources, and data collection for the simulation model inputs. While the larger Simul-Age project encompasses a broader range of inputs, the sub-study IV (the simulation study) focuses on a more specific set of data points. This narrower focus allowed for a more in-depth analysis of particular aspects of housing adaptation and accessibility.

Furthermore, the focus on the health-related outcomes shifted between the study protocol and the studies included in this thesis. Initially, we aimed for other health outcomes to be included in the simulation models, such as self-perceived health and well-being. Earlier research indicated that there is an association between the conditions and maintenance of the physical housing environment and well-being (Guo et al., 2021). However, the systematic review (sub-study III) revealed a lack of studies explicitly addressing well-being in relation to the physical housing environment. As a result, this health outcome was excluded from the simulation study (sub-study IV). Similarly, for self-perceived health, we found mixed results in studies targeting the physical environment, leading to its exclusion from the simulation study as well.

It is worth noting that while international frameworks, like the WHO Housing and Health guidelines (2018) and national reports (SOU, 2015:85) on housing, older people, and health, follow similar principles in addressing public health issues as outlined in the EBPHF, they may not explicitly use the term "concise statement of the issue" or adhere to the same data collection methods. The importance of developing a concise statement of the issue is aptly captured by a quote from Yogi Berra used in Ross Brownson's book "Evidence-Based Public Health": "If you don't know where you are going, you will wind up somewhere else" (Brownson et al., 2010). This quote underscores both the challenge and necessity of clearly defining the issue at hand. The implementation of EBPHF strategies remains challenging, despite their resonance with most public health professionals and researchers (Brownson, Fielding & Maylahn, 2009).

Overall, developing a concise statement of the issue is a crucial step in public health research and policy making. It enables researchers and policy-makers to focus their efforts, and to identify key areas for investigation. Ultimately, the formulation of a concise statement of the issue can ensure that the research conducted effectively addresses policy-makers, and it is therefore an important step towards informed decision making (Brownson et al., 2010).

# Community input and quantifying the issue

The development of housing policies targeting older adults is facing issues on multiple levels, that is, on a municipal, national and even international level. A significant challenge in developing housing policies on both a municipal and national level, is the tendency of policymakers to prioritize other policies that promote direct economic growth (Buffel & Phillipson, 2018; Han et al., 2022). For instance, policymakers often favour housing supply for high income households instead of increasing the living situation for older adults by improving housing accessibility (Organisation for Economic Cooperation and Development (OECD), 2022). Only two relevant qualitative studies analysed housing provision plans of Swedish municipalities and put emphasis on housing policies in general. First, Andersén, Berglund-Snodgrass & Högström (2023) investigated housing policies in terms of housing provision planning and explored how Swedish municipalities interpret their responsibilities regarding housing provision planning. After analysing housing provision plans, they concluded that housing provision planning is a collaboration between different sectors and actors, rather than being a responsibility for particular sectors of political committees. Furthermore, they see housing policies as an issue for cross-sectoral policy-coordination. Furthermore, Granath Hansson's (2021) qualitative study on municipal housing strategies for homeless people in Sweden puts emphasis on social housing initiatives. Granath Hansson's analysis of policy documents and interviews with municipal representatives from six Swedish cities reveals that social housing targets not only individuals with special needs or addictions but also older adults without social problems. At the date of writing this thesis, no other qualitative study has explored the current and future housing policy priorities to improve housing accessibility for the population ageing in place, which this thesis set out to do.

The policy study (sub-study II) revealed that there is a lack of multisectoral policy attempts between the legal, organizational, socio-demographic, and political levels. Overall, a collaboration between these four policy levels was missing, which leads to a fragmentation and the ineffective implementation of housing policies. While the two qualitative studies by Andersén, Berglund-Snodgrass & Högström (2023) and Granath Hansson (2021) contributed to the field of housing policies, they did not specifically focus on housing policies for the population ageing in place. However, to some extent they align with our recommendation for a multisectoral policy approach. Both studies emphasize the need for greater collaboration and coordination of housing policies across all policy levels.

One way forward is to understand the interconnectedness of housing policies since this is crucial for their successful implementation at different policy levels. For instance how housing policies are connected with other sectors such as social services or health care. By improving housing accessibility, the use of home health care or care facilities can potentially be reduced and in turn save public expenditure

(Slaug et al., 2017). Through the use of a multisectoral approach to housing policies, policymakers can create more effective strategies that address the complex needs of the ageing population while benefiting society as a whole. This approach not only supports those ageing in place but also contributes to the creation of more accessible and adaptable housing stock for future generations.

# Determining what is known through scientific literature

The systematic review aimed to synthesize the evidence on the relationships between physical housing characteristics or housing accessibility and different aspects of health among community-living older people (60 years and older). Three themes emerged through the analysis: (a) interventions by home modifications targeting housing features, both at entrances and indoors; (b) non-intervention studies targeting indoor features; and (c) non-intervention studies targeting entrance features. However, the collective body of evidence from the included studies was assessed as being very low, which underscores the importance of future studies in this field having a higher methodological quality. To my knowledge, there is a scarcity of systematic reviews focusing on physical housing characteristics or housing accessibility and their impact on the health of community dwelling people aged 60 and older. However, the findings can be contextualized within the broader landscape of two existing reviews (Ige et al., 2019; Garin et al., 2014) that addressed similar topics. Our review found no significant association between interventions by home modifications, non-intervention studies targeting indoor features, and quality of life. This contrasts with the results of Ige et al. (2019) who found that housing refurbishment and modifications, provision of adequate heating, and improvements to ventilation and water supply were associated with improved quality of life and other outcomes, such as respiratory improvement and mental health, on the general population. These contrasting results may be attributed to the differences between housing modifications, for instance the removal of thresholds and housing refurbishments, that is, the modernization or maintenance of existing housing. Furthermore, housing interventions may differ from one country to another and are often tailored to individual needs (Thordardottir et al., 2018). A comparison and generalization between housing interventions and their effects on health is, therefore, problematic.

Another challenge is, that there is a high variability of definitions and measures of quality of life; a comparison between studies is therefore challenging (Crist, 2000). The review from Garin et al. (2014) summarized the evidence on the built environment (including housing) and different health outcomes (physical health, mental health and life satisfaction) in community-dwelling people aged 50 or older. Given that Garin et al. (2014) focused on a younger population, they found a link between home size, housing type, usability, interior environment, and the health

outcomes of quality of life, life satisfaction, and well-being. These results also contrast with our findings, as we did not observe a clear association between physical housing characteristics and quality of life. The discrepancies could be due to the problematic comparison, as Garin et al. (2014) focused on individuals aged 50 and older, while our study investigated community-dwelling individuals aged 60 and older. To conclude, while our systematic review did not find significant associations between physical housing characteristics and quality of life among older adults, the contrasting results from other reviews highlight the complexity and variability in this field.

To better understand this relationship, future research is needed on the population aged 60 and older that has a higher methodological quality. To close this gap, future research might benefit from using robust study designs. For instance, randomized controlled trials with larger sample-sizes could be employed to increase the statistical power, or well-designed longitudinal studies in order to assess changes in health outcomes over time.

## Developing and prioritizing program and policy options

The current public health policy decision-making process is mostly driven by hot topics and the subjective assessment of policy-makers (Brownson et al., 2009). While the improvement of housing accessibility may currently not be the top policy priority in Sweden, the policy study (sub-study II) provided valuable insights into the policy solutions Swedish municipalities are considering for the future to support the population ageing in place.

During the research circle, the key actors and senior citizens identified seven policy priorities which span across legal, organizational, and socio-demographic policy levels. The community input section of this discussion already revealed that housing policies are complex; therefore, there is a need for sustainable and well-tailored policy options that enhance housing accessibility and thus the health of the older population. A contextualization with other findings is difficult as to my knowledge, no study focused on future policy priorities in Swedish municipalities that should support the population ageing in place. Therefore, our study is foundational for investigating the future housing policy priorities of five Swedish municipalities. After prioritizing future policy options, the key actors gave the highest priority to the coordination of accessibility issues at a national level, and cross-sectorial collaboration and the implementation of a multisectoral approach across all policy levels. This indicates a tendency towards a bottom-up policy approach, emphasizing the importance of municipal-level initiatives and community engagement in developing effective housing accessibility solutions on a national level. Policy development looked at through the lens of a bottom-up approach can be highly

beneficial in addressing complex societal issues such as housing policies. It has the potential to save public expenditure since interventions are more likely to be accepted by the general public (Voelker, 2017). There are policies on the municipal level, that can be taken into account and improved so they can be implemented on the national level. Even the WHO (2002) suggested earlier that the involvement of actors other than governments in policy processes can be beneficial for their implementation.

Given the complexity and the inter-connectedness of housing policies with other areas, for instance, environmental sustainability, health, mobility, and accessibility, a collaboration between different policy levels and governances such as the combination of a top-down and bottom-up approach, might be beneficial instead of considering policies in isolation (Howden-Chapman & Chapman, 2012; Dahlgren & Whitehead, 1991). Also, the United Nations' Sustainable Development Goals put emphasis on the interconnectedness of policies and the need for addressing several goals simultaneously (United Nations, 2015). Therefore, in order to make the most informed decisions on housing policies, policy-makers would benefit from viewing policies alongside each other, in order to profit from co-benefits and synergies (WHO, 2018). Even if housing accessibility policies are currently not prioritized by policy-makers in Sweden, the results highlight the need for sustainable housing policies that address housing accessibility for the population ageing in place.

# Evaluation of the policies

The simulation study (sub-study 4) revealed that the large-scale barrier removal policy could potentially delay or prevent cases of dependence in I-ADL and P-ADL, and demonstrated long-term cost benefits in comparison to care-as-usual. Another finding was that the large-scale barrier removal policy demonstrated early cost-benefits already after two to four years within the 20-year period, which is in line with what Slaug et al. (2017) demonstrated in their study.They investigated potential short and long-term costs and gains of housing accessibility policy changes on I-ADL and the usage of home services among community-dwelling people aged 80 to 89 in Sweden and Germany. Slaug and colleagues (2017) not only focused on the indoor environment but also on entrances and removed potential barriers, such as doors at the entrance that do not stay open or insufficient manoeuvring space in the kitchen. Their large-scale barrier removal policy scenario demonstrated potential savings after more than one year in Sweden and two and a half years in Germany. However, the implementation of large-scale barrier removal policies may face obstacles, such as limited budgets, the focus on other policies, or the lack of objective assessments of policy-makers (Brownswon et al., 2009). Therefore, it is important to increase the collaboration between various sectors, stakeholders, and

individuals to implement a multisectoral approach across all policy levels (Dahlgren and Whitehead, 1993).

Furthermore, while the specific environmental barriers causing accessibility issues for ageing individuals may vary to some degree based on the different samples studied, extensive research has consistently identified certain key barriers. Two barriers that frequently emerge in the literature are the absence of grab bars in hygiene areas and the presence of thresholds between rooms. These findings are supported by numerous studies, including work by Granbom et al. (2016), Pettersson et al. (2017), Slaug et al. (2017), Szanton et al. (2011), Taylor et al. (2020), and Slaug, Granbom & Iwarsson (2024). Given the strong and consistent evidence, any implementation of a large-scale barrier removal policy should, at a minimum, prioritize addressing these two specific environmental barriers.

Perhaps, surprisingly, the home visit with preventive barrier removal policy did not demonstrate cost-benefits over a 20-year period in comparison to care-as-usual. Earlier research has indicated that preventive home visits are cost-effective. Zingmark et al. (2019) evaluated the cost-effectiveness of a preventive home visit and senior meetings intervention for community-dwelling older people in Sweden by using Markov models. Their results suggest gains in QALY and the reduction of societal costs. It should be noted, however, that a preventive home visit as stated in Zingmark et al. (2019) and our study differ both in terms of their intervention type (preventive home visit with senior meetings vs. home visit with preventive barrier removal), and the type of analysis being used (cost-effectiveness vs. cost-benefit analysis). However, even if the home visit with preventive barrier removal did not demonstrate a cost-benefit, it demonstrated a high impact on living independently. After one year of policy implementation, 777 individuals could continue living independently, and by year 20, this number increased to 5,991 individuals of the Swedish population aged 65 and older, compared to care-as-usual. Moreover, the barriers targeted in the home visit with barrier removal policy are closely linked to fall risks, suggesting that this policy could potentially reduce future fall accidents in homes. Falls among older adults pose a significant economic burden on society. In Sweden, falls involving individuals aged 65 and older result in an annual cost of approximately 9 billion SEK to society (Swedish Civil Contingencies Agency, 2013). The home visit with preventive barrier removal policy, despite not showing direct cost benefits, remains a valuable option due to its substantial impact on living independently and the potential for reducing fall-related incidents.

# Strengths and limitations

*Limitations due to the sampling, transferability, and generalizability*

*The policy study*

The sampling in sub-study II, the policy study, lacked of a major Swedish municipality. This could have led to a potential selection bias and might affect the transferability of studies. However, our primary objective was to capture a range of experiences and insights rather than a comparison between the municipalities. By taking geographic location, socio-economic conditions, and different ethnicities into account, we ensured representativeness. Furthermore, we saw a saturation of themes during the analysis, and believe therefore, that the inclusion of a major city would not have altered the main findings of our study. Furthermore, there was no ethnic diversity in the policy study, which might have narrowed the perspectives and experiences of older adults on housing policies. However, the study results allow a deeper understanding of housing policies through the lens of Swedish municipalities and Swedish older adults.

*The simulation study*

In sub-study IV, the simulation study, three important limitations need to be addressed. First, the calculation of the prevalence of environmental barriers in the Swedish ordinary housing stock relies on data from several projects (Iwarsson & Isacsson, 1996; Iwarsson et al., 2007; Kylén et al., 2014; Nilsson & Iwarsson, 2013; Schmidt et al., 2022). Many of the included studies were conducted in Southern Sweden, meaning that this might have affected the study's ability to represent the Swedish housing stock as a whole, which in turn presents a potential impact on the generalizability of the results. However, previous studies concluded that there is some level of consistency among environmental barriers in the ordinary Swedish housing stock. They found that environmental barriers were common across various building periods and housing types throughout the country (Granbom et al., 2016; Slaug, Granbom & Iwarsson, 2024), suggesting a degree of national representation despite the southern focus in the calculation of the prevalence of environmental barriers. Second, the over-representation of bathroom barriers in sub-study IV, the simulation study, might have limited the generalizability of our findings to other areas of the home. However, this focus is justified, as bathrooms are critical spaces for housing accessibility (Naik & Gill, 2005; Zingmark & Bernspång, 2011; Leung et al., 2018; Slaug, Granbom & Iwarsson, 2024), particularly for older adults and individuals with mobility limitations. Our analysis employed two distinct approaches: the home visit with preventive barrier removal policy, which concentrated on the most common housing adaptations, and the large-scale barrier removal policy, which calculated barriers with the highest impact. Both approaches independently highlighted the bathroom as a crucial area for housing accessibility.

Third, there might be an underestimate of social benefits in relation to barrier removal. That is, we adopted a more conservative approach by assuming that each policy intervention would benefit only one individual at a time. However, in reality, the impact is likely to be more widespread. Both the large-scale barrier removal policy and the home visit with preventive barrier removal policy would likely benefit multiple individuals due to co-habitation. For instance, in households where multiple people live together, removing a single barrier could improve housing accessibility for all residents. This multiplier effect could significantly increase the overall social benefits of these interventions. Even if our study might have underestimated the true value of cost-benefits, the large-scale barrier removal policy demonstrated cost-benefits over the 20-year period in comparison to care-as-usual; therefore, we assume that the actual cost-benefits of the policies may be even more favourable than our results indicate.

*Risk for information loss*

*The systematic review*

In sub-study III, the systematic review, primarily studies in English were included, which could potentially introduce language bias, in turn, leading to overlooking relevant studies on housing and health published in other languages. However, we screened the abstracts of the few studies in different languages, and thus concluded that the inclusion of mainly publications in English was unlikely to have affected our findings.

*The simulation study*

In sub-study IV, the simulation study, there are some potential limitations that need to be discussed. First, the data harmonization aimed to ensure consistency across all datasets; however, there was a variability in assessment tools in the measurement of ADL, which could have affected the comparison of results. For instance, in the SNAC sample, the construct of ADL was measured using both ordinal and dichotomized scales. Previous research by Axmon et al. (2019) has shown that a four-graded ADL scale offers greater statistical power compared to three-graded or dichotomous scales. However, to ensure consistency across all datasets, we decided to use a dichotomous variable, that is, the participants were either dependent in ADL or independent. However, to minimize the risk for information loss, we documented all the harmonization steps meticulously, and had frequent discussions between all co-authors on the data harmonization. Second, the relationship between ADL independence/dependence and relocating to special housing, particularly for people with dementia, is complex. We acknowledge a potential discrepancy in the measurement of this transition, as there might be individuals who are independent in the assessed ADLs but still move to special housing due to other factors. For instance, caregiver burden, safety concerns or individuals may still be able to

perform daily hygiene but struggle with medication management due to cognitive decline (Franco et. al., 2021).

*Limitations due to the COVID-19 pandemic*

The COVID-19 pandemic impacted the data collection for both sub-study II, the policy study, and sub-study IV, the simulation study.

*The policy study*

In sub-study II, the policy study, the interviews and the research circle were primarily held online, which might have affected the credibility of the findings. In-person interviews typically facilitate a more natural flow of conversation and would have allowed for observations of governance structures and municipal administration. However, we were able to gain rich qualitative data through the online interviews and the research circle. To strengthen the study, we included participants who represented a gender-balanced sample with a variation of professional positions, and we applied a participatory approach by the inclusion of senior citizens and the use of the research circle methodology.

*The simulation study*

Sub-study IV, the simulation study faced similar challenges due to COVID-19 restrictions, which prevented us from conducting the Housing Enabler inventory in the initially planned 50 dwellings across five partner municipalities involved in this PhD project. Due to the pandemic, only 12 dwellings in two municipalities (Eslöv and Örebro) could be assessed. To address this limitation, we supplemented our data with additional datasets to gain a more accurate representation of the Swedish housing stock.

# Conclusions

Housing and health are domains, that are multi-dimensional, interrelated, and complex (Howden-Chapman & Chapman, 2012). This thesis provides valuable insights into housing policies and their impact on health among older adults ageing in place, contributing to a deeper understanding of the synergies between these domains. This research contributes to the evidence-based public health framework by developing a concise statement of the issue, incorporating community input, determining what is known through scientific literature, and evaluating potential policies. It highlights the need for a multisectoral approach that integrates legal, organizational, and socio-demographic dimensions to effectively address the complexity of housing policies. Furthermore, it underscores the importance of community engagement and collaboration among various stakeholders in developing housing policies. This thesis also identifies gaps in the current literature regarding the relationship between housing characteristics and health outcomes for older adults. It calls for future research to employ robust methodologies to better understand these dynamics. By prioritizing policy options that facilitate accessibility and collaboration across sectors, policymakers can create more effective strategies that support the ageing population while also benefiting society as a whole. Furthermore, this study revealed, that a large-scale barrier removal policy could potentially delay or prevent cases of dependence in I-ADL and P-ADL, since it demonstrated long-term cost benefits in comparison to care-as-usual among people aged 65 and older. Finally, this thesis also suggests that addressing environmental barriers and enhancing housing accessibility are crucial steps to ensuring that older adults can live independently in their communities, creating a more inclusive environment for people with functional and/or cognitive limitations.

# Implications, relevance, and future research

## Implications for policy-makers

- Simulation models have the potential to communicate evidence-based research results in such a way that policy-makers are able to understand and implement them. The results of this thesis can be used to develop an action plan for the implementation of housing policies. To do so, a few key questions should be focused on how to achieve a successful implementation of multisectoral housing policies by policy-makers: Who pays for the implementation of the housing policies? What benefits are expected? Who will profit from those benefits?
- Bridging the gap through multisectoral workshops, that is between the municipalities and other stakeholders, such as private housing companies. Hands-on training on simulation models can be beneficial for policy-makers on how to use the models, and to answer relevant key questions before the implementation of housing policies, which in turn, has the potential to save public expenditure.
- Increase the communication between all committees and councils within the municipality to improve long-term collaboration on housing policy matters.

## Implications for public health professionals

- While this thesis primarily focuses on the responsibilities of municipalities, it is also crucial to highlight the significant need for preventive measures among senior citizens. For instance, public health professionals play an important role in addressing this challenge by developing strategies that bridge research findings and individual knowledge. Therefore, to enhance the knowledge base among individuals, low-threshold educational interventions, such as seminars or workshops, could be used to equip older adults with information so they are able to make informed decisions about accessible housing options.

- Advocate for age-friendly and accessible housing environments to promote health across the whole lifespan, and to reduce health inequities.
- Increase the early engagement in interdisciplinary teams to combine environmental, health, community, and economic perspectives when planning housing policies and interventions.

## Future research

- Overall, future studies should be integrated into existing multi-level policy frameworks to identify challenges across different policy levels, such as political, organizational, environmental, and socio-demographic, and to create more effective housing policy strategies for the population ageing in place.
- Further studies should focus on economic evaluations, such as cost-utility or cost-effectiveness analyses, to examine the impact of housing policies on quality-adjusted life years (QALYs) or gained life years.
- Randomized controlled trials with larger sample-sizes could be employed to increase the statistical power, or well-designed longitudinal studies, to assess changes in health outcomes over time.
- To gain a more comprehensive understanding of the interrelation between housing environments and various health outcomes, future research should expand the scope of economic evaluations. These studies should investigate additional health outcomes, such as participation, quality of life, self-perceived health, and well-being in relation to the housing environment.

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*To my colleagues at CASE*

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*The magical number 4: A recipe for success*

When I started my PhD studies, someone asked me early on: "Won't it be tricky having four supervisors? You'll need to juggle different views and find the balance between four different opinions?" The only problem I saw was finding suitable dates for the supervision in our busy calendars. All four of you supported me in unique ways and challenged me to push boundaries. However, to succeed in the role of a PhD student, a simple three-step recipe should be followed:

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*It takes a village*

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# Author's contribution to the sub-studies

*Sub-study I, the study protocol:*

Provision of details regarding data sources and data collection, and providing critical input on the manuscript.

*Sub-study II, the policy study:*

Leading the development of the interview guide, and participant recruitment. Conducting interviews under supervision of my supervisor and structural planning of the research circle meetings. Performing the in-depth data analysis and authoring the first draft of the manuscript.

*Sub-study III, the literature review:*

Leading the Prospero application process, conducting the literature search across databases, study selection and data extraction. Evaluation of the scientific evidence, data analysis, and synthesis, as well as writing the first draft of the manuscript.

*Sub-study IV, the simulation study:*

Primary data collection through Housing Enabler assessments in two municipalities, secondary data retrieval, and data harmonization. Creating the decision model, identifying suitable interventions based on the results of the policy study. Data retrieval on costs and cost calculation of the proposed policy interventions and related health outcomes. Providing input on the analysis and drafting the first version of the manuscript.

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# Appendices I-IV

## Appendix I

*Recruitment material for sub-study II (the policy study)*

*Studie om kommuners arbete kring tillgänglighetsfrågor i boendet:*
*en del av forskningsprojektet ”Simul-Age”*

*Informationsbrev angående deltagande i en delstudie i forskningsprojektet ”Simul-Age”*

*Bakgrund och syfte*

Forskningsprojektet Simul-Age handlar om tillgängligheten i det ordinära boendet och möjligheterna att åldras i det egna hemmet. För att stödja möjligheterna att åldras i det egna hemmet behöver boendet utformas eller anpassas efter behoven hos människor som åldras såväl med som utan begränsningar i funktionsförmåga, som ofta hör till det normala åldrandet. Syftet med denna delstudie är att undersöka hur fem strategiskt valda svenska kommuner arbetar för att öka tillgängligheten i det ordinära bostadsbeståndet och att tillsammans med några nyckelpersoner inom dessa kommuner samtala om bostadspolitiska åtgärder och prioriteringar.

*Hur går studien till?*

Om du vill delta in den här studien innebär det att du får besvara ett antal frågor i en intervju som vi uppskattar kommer att vara ca 45-60 minuter. Intervjun kommer att handla om din kommuns arbete och policys kring bostadsanpassningar och andra åtgärder för att öka tillgängligheten i boendet. Intervjun kommer att dokumenteras med ljudupptagning. I senare skeden av projektet kommer du också att tillfrågas om att delta i gruppdiskussioner (forskningscirklar) och workshops, tillsammans med nyckelpersoner från de andra strategiskt utvalda kommunerna. Även dessa tillfällen kommer att dokumenteras med ljudupptagning. Om du samtycker till att delta i studien anmäler du dig genom att skriva under blanketten ”Informerat samtycke” i två exemplar. Ett exemplar behåller du själv och ett lämnar du till forskaren som ger dig det här informationsbrevet.

*Frivillighet*

Deltagande är frivilligt och du har rätt att när som helst avbryta din medverkan utan särskild förklaring. Avbryter du tas hela intervjun bort. Att avbryta deltagandet innebär inga negativa konsekvenser för dig.

*Vad händer med informationen som samlas in?*

Information som samlas in kommer att lagras och bearbetas i enlighet med gällande lagstiftning och riktlinjer. Lunds universitet ansvarar för dina personuppgifter, vilka kommer att behandlas i enlighet med EU:s dataskyddsförordning (GDPR). Mer information om behandling av personuppgifter vid Lunds universitet hittar du på denna länk: https://www.lu.se/start/behandling-av-personuppgifter-vid-lunds-universitet. Dina intervjusvar kommer inte att kunna identifieras via de forskningsresultat som presenteras senare. Dina intervjusvar kommer att ingå i ett samlat resultat. Enbart forskarna kommer att ta del av dina intervjusvar. Du har rätt att skriftligen begära ett registerutdrag där du kan se vilka uppgifter om dig som registrerats och behandlats i projektets databas.

*Ansvarig för studien*

Lunds universitet är forskningshuvudman. Biträdande forskare Björn Slaug vid Institutionen för hälsovetenskaper, Medicinska fakulteten och CASE – ett centrum för forskning om åldrande och stödjande miljöer (www.case.lu.se/), är huvudansvarig forskare och har det vetenskapliga ansvaret för studien. Flera forskare är engagerade, med Docent Lisa Ekstam och Doktorand Christina Heller som kontaktpersoner. Om du önskar ytterligare information om projektet är du välkommen att ringa eller skriva till:

| | | |
|---|---|---|
| Kontaktperson:<br>Lisa Ekstam<br>Tel 046 – 222 1998 | Kontaktperson:<br>Christina Heller<br>Tel 046 – 222 1868 | Ansvarig forskare:<br>Björn Slaug<br>Tel 046 – 222 1838 |
| e-post:<br>lisa.ekstam@med.lu.se | e-post:<br>christina.heller@med.lu.se | e-post:<br>bjorn.slaug@med.lu.se |

# Appendix II

*Interview guide for sub-study II (the policy study).*

| |
|---|
| ID number |
| Datum för intervjun |
| Namn på intervjuare |
| Bakgrundsinformation |
| Kommun |
| Befattning inom kommunen |
| Antal år i kommunen |
| Ålder |
| Kön |

| **Inledning** |
|---|
| • Kan du berätta litet om din befattning och vilka dina uppgifter inom kommunen är?<br>• Hur ser du allmänt på standarden i det kommunala bostadsbeståndet, finns det behov av större renoveringar och standardförbättringar?<br>• När en renovering genomförs i en byggnad, vad anser du som viktiga åtgärder för att stödja ökad tillgänglighet i boendet? |
| **Tema 2: Policys (Lagar, författningar, riktlinjer, lokala rutiner)** |
| • Vilka policys och riktlinjer finns idag i kommunen som rör tillgänglighet i bostäder (för den åldrande befolkningen)?<br>• Vilka policys och riktlinjer följer ni när det byggs **nya** bostäder i kommunen?<br>• Med vilka andra aktörer (utanför kommunen) arbetar ni tillsammans för att förbättra tillgängligheten i bostäder för äldre?<br>• Vilka utmaningar brottas ni med när det gäller omsättningen/tilllämpning av policys?<br>• Anser du att det är för mycket eller för litet styrning, när det gäller tillämpning av policys? På vilket sätt?<br>• Om du tänker på olika beslut, lagar och policys, vilket behov finns det av att justera dessa för att bättre stödja personer med funktionsnedsättning?<br>• I vilken utsträckning uppfattar du att politiska beslutsfattare har den kunskap som krävs för att fatta informerade beslut om policys som rör bostäders tillgänglighet?<br>• Anser du att beslut som rör bostäders tillgänglighet tas på rätt "nivå" i er kommun? |
| **Tema 3: Insatser/åtgärder** |
| • Vilka regelverk och policys följer ni när det gäller att anpassa befintliga bostäder (för den åldrande befolkningen)?<br>• Har ni några interna riktlinjer ni följer vad gäller bostadsanpassningar i er kommun?<br>• Vilka är de vanligaste bostadsanpassningarna i er kommun?<br>• Vilka bostadsanpassningar eller andra insatser för mer tillgängligt boende kostar enligt din uppfattning mest i dagsläget?<br>• I vilken utsträckning avsätts tillräckliga ekonomiska resurser för att förbättra tillgängligheten i boendet enligt din uppfattning?<br>• Finns det enligt din uppfattning också ekonomiska vinster att göra med att förbättra tillgängligheten i boendet? (till exempel att bättre förutsättningar för äldre att vara oberoende i vardagsaktiviteter kan resultera i minskat behov av hemtjänst)?<br>• Kan du tänka dig andra vinster, som har med bättre tillgänglighet i boendet att göra, som kan uppväga ekonomiska kostnader? (till exempel höjd livskvalitet, ökade möjligheter till delaktighet, utjämnande av skillnader mellan olika grupper, gynnande av svaga grupper i samhället etc)? |

**Appendix II continued.**

| **Tema 3: Insatser/åtgärder fortsättning** |
| --- |
| • Vilka andra åtgärder har det genomförts (förutom individuella bostadsanpassningar) i kommunen de senaste åren för att förbättra tillgängligheten i det ordinära bostadsbeståndet?<br>• Finns det några förebyggande insatser som du/ni anser att man skulla kunna göra för att minska antalet individuella bostadsanpssningar? |
| **Tema 4: Framtiden** |
| • Om du tänker framåt, ca 10-15 år, vilka frågor kring tillgänglighet tror du då kommer att vara aktuella i er kommun?<br>• Har du idéer om andra möjliga lösningar som kan öka tillgängligheten i boendet för en åldrande befolkning än de ni har provat idag? |

# Appendix III

*Overall grading of scientific evidence, with a focus on health outcomes for sub-study III (the systematic review).*

| | | Factors that decrease the quality of the evidence | | | | | Factors that increase the quality of the evidence | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Authors | Health outcome | Limitations in study design | Indirectness | Imprecision | Inconsistency | Publication bias | Large effect | Plausible confounders | Dose-response gradient | Overall grading of scientific evidence |
| Clarke, 2014; García-Esquinas et al., 2016; Pérez-Hernández et al., 2018; Taylor et al., 2020; Yang & Sanford, 2011 | *Body functions* | -1 | -1 | -1 | -1 | 0 | 0 | 0 | - | ⊕◯◯◯ very low |
| García-Esquinas et al., 2016; Mitoku & Shimanouchi, 2014; Pérez-Hernández et al., 2018; Slaug et al., 2017; Szanton et al., 2011; Taylor et al., 2020; Tomioka et al., 2018 | *P-ADL & I-ADL* | -1 | -1 | -1 | -1 | 0 | 0 | 0 | - | ⊕◯◯◯ very low |
| González et al., 2020; Leung et al., 2018; Nakhodaeezadeh et al., 2017; Szanton et al., 2011; Taylor et al., 2020 | *Quality of life* | -1 | -1 | -1 | -1 | 0 | 0 | 0 | - | ⊕◯◯◯ very low |
| Leung et al., 2018; Yang & Sanford, 2011 | *Social participation* | -1 | -1 | -1 | 0 | 0 | 0 | 0 | - | ⊕◯◯◯ very low |
| Tomsone et al., 2013; Tsuchiya-Ito et al., 2019 | *Self-perceived health* | -1 | -1 | -1 | -1 | 0 | 0 | 0 | - | ⊕◯◯◯ very low |
| Kim et al., 2021; Tsuchiya-Ito et al., 2019 | *Life satisfaction* | -1 | -1 | -1 | 0 | 0 | 0 | 0 | - | ⊕◯◯◯ very low |

# Appendix IV

Abbreviations: **CASP-19**=Control, Autonomy, Self-Realization and Pleasure scale, **CASPAR**= Comprehensive Assessment and Solution Process for Aging Residents, **CSPS**= Continuously scored lower extremity Summary Performance Score, **DAD**=the Disability Assessment for Dementia, **EQ-5D**= EuroQol-5 Dimension, **ICECAP-O**= ICEpop CAPability measure for Older people, **I-ADL**=Instrumental Activities of Daily Living, **MBR**= Maximal Balance Range Tests, **MoCA**= Montreal Cognitive Assessment, **P-ADL**=Personal Activities of Daily Living, **PARTS/M**=Participation survey/mobility, **PPA**= Physiological Profile Assessment, **QoI**=Quality of Life, **SPPB**= Short Physical Performance Battery, **S-IQCODE**=Spanish Informant Questionnaire on Cognitive Decline in the Elderly, **TMIG-IC**=Tokyo Metropolitan Institute of Gerontology Index of Competence

**Note: significant values are bolded**

*Relationships between housing characteristics and different aspects of health for sub-study III (the systematic review).*

| **Body functions** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| Clarke, 2014 | Cross-sectional | Not applicable | Effect of bad housing features | Walking surface leading to building, ramp; stairs at entrance (study specific checklist) | Difficulty going out (study specific) | Logistic regression | **Stairs: OR 1.52; CI 1.21; 1.91** Ramp: OR 1.27; CI 0.98; 1.66 (several interaction effects also calculated) |
| García-Esquinas et al., 2016 | Cross-sectional | Not applicable | Effect of bad housing features | Walk-up building, no elevator (single item) | (1) SPPB<br>(2) Mobility lim.<br>(3) Agility lim. | Linear regression<br>Logistic regression<br>Logistic regression | (1) Est -0.02; CI -0.22; 1.18<br>(2) OR 0.90; CI 0.72; 1.13<br>(3) OR 0.97; CI 0.78; 1.21 |
| González et al., 2020 | Cross-sectional | Not applicable | Effect of good housing features | Physical home environment, i.e., decoration and location of home (HOME) | (1) S-IQCODE<br>(2) MoCa (cognitive function) | Logistic regression | **(1) OR 0.95; CI 0.92; 0.96**<br>(2) Not significant |
| Pérez-Hernández et al., 2018 | Longitudinal | 2 years | Effect of bad housing features | Walk-up building, no elevator (single item) | SPPB | Linear regression | Est -0.06; CI -0.26; 0.14 |

**Appendix IV continued.**

| Body functions continued | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| Taylor et al., 2020 | Randomized control trial | 6 and 12 months | Home modification intervention vs. control (care-as-usual) | Home hazards, e.g., lack of railings, raised thresholds, lack of lighting (Home Safety Assessment Tool) | (1) PPA<br>(2) SPPB<br>(3) CSPS<br>(4) MBR | Linear regression | Between group difference<br>(1) Est 0.1; CI -0.4; 0.5<br>(2) Est 0.2; CI -0.4; 0.8<br>(3) Est -0.06; CI -0.8; 0.2<br>(4) Est -8; CI -20; 4 |
| Yang & Sanford, 2011 | Cross-sectional | Not applicable | Effect of bad housing features | Physical home environment, barriers and facilitators (CASPAR) | Mobility limitation, ease-difficulty (study specific) | Spearman correlation | **Corr; Up/down stairs 0.303**<br>**Corr; Home space 0.364**<br>**Corr; Pathways 0.276**<br>**Corr; Door 0.297**<br>**Corr; Toilet 0.268**<br>**Corr; Tub/shower 0.257**<br>**Corr; Kitchen space 0.391**<br>**Corr; Kitchen appl 0.443**<br>**Corr; Kitchen upper cabin 0.269**<br>**Corr: Kitchen lower cabin 0.627**<br>**Corr; Bedroom space 0.468**<br>**Corr; Bedroom bed 0.393**<br>**Corr; Bedroom closet 0.570** |

**Appendix IV continued.**

| **Self-perceived health** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| Tomsone et al., 2013 | Cross-sectional | Not applicable | Effect of bad housing features, i.e., in Latvia and Sweden (respectively) | Physical barriers in the home environment, e.g., high thresholds, narrow door openings, stairs without handrails (Housing Enabler) | SF-36 single item (stratified by country and level of ADL dependence) | Ordinal regression | Entrances Latvia<br>**ADL Indep.; Est 0.09, CI 0.03; 0.15**<br>ADL Dep.: Est -0.07; CI -0.18; 0.04<br>Entrances Sweden<br>ADL Indep.: Est 0.03; CI -0.03; 0.09<br>ADL Dep.: Est -0.05; CI -0.05; 0.004<br>Indoor Sweden<br>**ADL Indep.: Est -0.08; CI -0.14; -0.02**<br>ADL Dep.: Est -0.04; CI -0.09; 0.007<br>(All others not included in this analysis step) |
| Tsuchiya-Ito et al., 2019 | Cross-sectional | Not applicable | Effect of bad housing features | Accessibility of housing environment, e.g., difficulty entering or leaving the home, unable to climb stairs, difficulty maneuvering within rooms, no railings although needed (Healthy housing environment) | Self reported health (stratified by level of ADL dependence) | Logistic regression | ADL Indep.: OR 1.40; CI 0.91; 2.14<br>ADL Dep.: OR 1.46; CI 0.85; 2.48 |

**Appendix IV continued.**

| **Quality of life** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| González et al., 2020 | Cross-sectional | Not applicable | Effect of good housing features | Physical home environment, i.e., decoration and location of home (HOME) | ICECAP-O | Logistic regression | **OR 6.54; CI 1.75; 24.46** |
| Leung et al., 2018 | Cross-sectional | Not applicable | Effect of good housing features | Indoor built environment, space and distance; building services, e.g., lighting, ventilation; supporting facilities, e.g., handrails, colour; barrier-free design (study specific checklist) | Overall QoL (study specific) | Unspecified regression analysis | **Est. Furniture and fixtures 0.092**<br>**Est. Lighting 0.149**<br>**Est. Handrails -0.125**<br>Est. Barrier-free design not reported<br>(CI not reported) |
| Nakhodaeezadeh et al., 2017 | Cross-sectional | Not applicable | Effect of good housing features | Characteristics of entrance, hall, lounge, kitchen, double bedroom, single bedroom, alternative bathroom, cupboard, general items, and assistive technology (EVOLVE) | CASP-19 | Spearman correlation | **Corr coeff 0.279** |
| Szanton et al., 2011 | Randomized controlled trial (pilot) | 24 weeks | Home modification intervention vs control group (attention sessions) | Physical barriers in the home environment, e.g., holes in floors, uneven carpeting, and lack of railings or banister (Client Clinician Assessment protocol) | (1) EuroQOL<br>(2) EQ-5D | Difference in means between groups | **(1) Cohen D 0.89**<br>**(2) Cohen D 0.48**<br>(CI not reported) |
| Taylor et al., 2020 | Randomized controlled trial | 6 and 12 months | Home modification intervention vs. control (care-as-usual) | Home hazards, e.g., lack of railings, raised thresholds, lack of lighting (Home Safety Assessment Tool) | EQ-5D | Linear regression | Est. 0.02; CI -0.04; 0.07 |

**Appendix IV continued.**

| **Life satisfaction** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| Kim et al., 2021 | Cross-sectional | Not applicable | Effect of good housing features | Perceived housing accessibility and usability (study specific checklist) | To what degree participants were satisfied with their life | Linear regression | **Est. 0.22; CI -0.015; 0.04*** |
| Tsuchiya-Ito et al., 2019 | Cross-sectional | Not applicable | Effect of bad housing features | Accessibility of housing environment, e.g., difficulty entering or leaving the home, unable to climb stairs, difficulty maneuvering within rooms, no railings although needed (Healthy housing environment checklist) | How would you rate your life satisfaction in the last three days? (stratified by level of ADL dependence) | Logistic regression | ADL Indep.: OR 1.08; CI 0.73; 1.60<br>ADL Dep.: OR 1.30; CI 0.77; 2.16 |

**Note: Significant finding reported in the original article, but inconsistent with CI, which seems to be duplicated from another variable.*

**Appendix IV continued.**

| Personal ADL (P-ADL) and Instrumental ADL (I-ADL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| García-Esquinas et al., 2016 | Cross-sectional | Not applicable | Effect of bad housing features | Walk-up building, i.e. no elevator<br>(single item) | Lawton & Brody Scale<br>(I-ADL) | Logistic regression | OR 1.33; CI 0.87; 2.03 |
| Mitoku & Shimanouchi, 2014 | Longitudinal | 1 year<br>2 years<br>3 years | Home modification vs no home modification | Housing adaptations, e.g., installation of handrails, elimination of floor height differences, change of lavatory basin, change of floor materials, change of door etc.<br>(Study specific protocol) | Progression of frailty, including mortality<br>(P-ADL) | Chi-square | After 1 year: 48.6% vs. 58.7%<br>After 2 years: 62.9% vs. 71.9%<br>After 3 years: 79.5% vs. 84.8% |
| Pérez-Hernández et al., 2018 | Longitudinal | 2 years | Effect of bad housing features | Walk-up building, i.e. no elevator<br>(single item) | Lawton & Brody Scale<br>(I-ADL) | Logistic regression | OR 1.26; CI 0.82; 1.92 |
| Slaug et al., 2017 | Longitudinal (with a simulation modeling design) | 1 year | Effect of bad housing features, i.e., in Germany and Sweden (respectively) | Physical barriers in the home environment, e.g., high thresholds, narrow door openings, stairs without handrails; measure of housing accessibility problems<br>(Housing Enabler) | (1) Cooking<br>(2) Shopping<br>(3) Cleaning<br>(4) Transport.<br>ADL staircase (I-ADL) | Logistic regression | Germany<br>**(1) OR 1.004; CI 1.000; 1.008**<br>**(2) OR 1.003; CI 1.000; 1.007**<br>(3) OR 1.001; CI 0.998; 1.005<br>**(4) OR 1.005; CI 1.001; 1.008**<br>Sweden<br>**(1) OR 1.005; CI 1.002; 1.009**<br>**(2) OR 1.004; CI 1.001; 1.008**<br>**(3) OR 1.011; CI 1.007; 1.015**<br>**(4) OR 1.004; CI 1.001; 1.007** |

**Appendix IV continued.**

| Personal ADL (P-ADL) and Instrumental ADL (I-ADL) continued | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| Szanton et al.,<br>2011 | Prospective randomized control pilot trial | 24 weeks | Home modification intervention vs control group (attention sessions) | Physical barriers in the home environment, e.g., holes in floors, uneven carpeting, and lack of railings or banister<br>(Client Clinician Assessment protocol) | (1) Lawton & Brody Scale (I-ADL)<br>(2) ADL staircase<br>(P-ADL) | Comparison of ADLs with difficulties | **(1) P-ADL: Cohen's Delta 0.63**<br>**(2) I-ADL: Cohen's Delta 0.62**<br>(CI not reported) |
| Taylor et al.,<br>2020 | Randomized control trial | 6 and 12 months | Home modification intervention vs. control (care are as usual) | Home hazards, e.g., lack of railings, raised thresholds, lack of lighting<br>(Home Safety Assessment Tool) | DAD: Disability assessment for dementia<br>(P-ADL) | Linear regression | Est. -3.3; CI -8.7; 2.2 |
| Tomioka et al., 2018 | Population-based longitudinal cohort study | 3 years | Effect of bad housing features, i.e., in men and women (respectively) | Walk-up building, i.e. no elevator<br>(single item) | TMIG-IC<br>(I-ADL) | Logistic regression | Men: OR 0.90; CI 0.71; 1.14<br>**Women: OR 0.72; CI 0.52; 0.99** |

**Appendix IV continued.**

| **Social participation** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Authors | Study design | Follow-up | Effect/comparison | Exposure (assessment tool) | Outcome | Analysis | Effect size/measure of relationship |
| Leung et al., 2018 | Cross-sectional | Not applicable | Effect of good housing features | Indoor built environment, space and distance; building services, e.g., lighting, ventilation; supporting facilities, e.g., handrails, color; barrier-free design (study specific checklist) | Social relationships (study specific) | Unspecified regression analysis | **Est. Furniture and fixtures 0.09**<br>**Est. Lighting 0.11**<br>Est. Handrails Not reported<br>Est. Barrier-free design not reported<br>(CI not reported) |
| Yang & Sanford, 2011 | Cross-sectional | Not applicable | Effect of bad housing features | Physical home environment, e.g., height and location of toilet (CASPAR) | PARTS/M (community participation) | Unspecified regression analysis | **OR bathroom, toilet space: 46.7**<br>**OR bathroom, toilet: 25.0**<br>**OR bathroom, tub/shower space: 29.0**<br>**OR bathroom, tub/shower: 8.0**<br>Other areas not significant |

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# Housing Policies to Promote the Health of a Population Ageing in Place: Comparisons Using Simulation Modelling

This thesis aims to increase the knowledge of housing and housing policies as determinants of health among older people ageing in place. By utilising simulation models, Christina Löfvendahl analyses and compares the potential societal gains and costs for different large-scale housing policy interventions. Her thesis underscores the importance of adopting a multisectoral approach to housing policies. By addressing environmental barriers and improving housing accessibility, Christina's thesis demonstrates how policymakers can develop more effective strategies to support ageing in place, ultimately benefiting society as a whole. Her findings have significant implications for policy makers, public health professionals, and urban planners, highlighting the interconnectedness of housing policies and health outcomes.

## About the Author

Christina Löfvendahl is a trained Geriatric Nurse with a specialization in Intensive Care, bringing several years of clinical experience to her research. She holds a Bachelor's degree in Health and Care Management and a Master's degree in Public Health. Her PhD project was conducted within the Active and Healthy Ageing research group, which is affiliated with the Centre of Ageing and Supportive Environments (CASE) at the Department of Health Sciences, Lund University. Furthermore, Christina is affiliated with the Swedish National Graduate School on Ageing and Health (SWEAH).

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