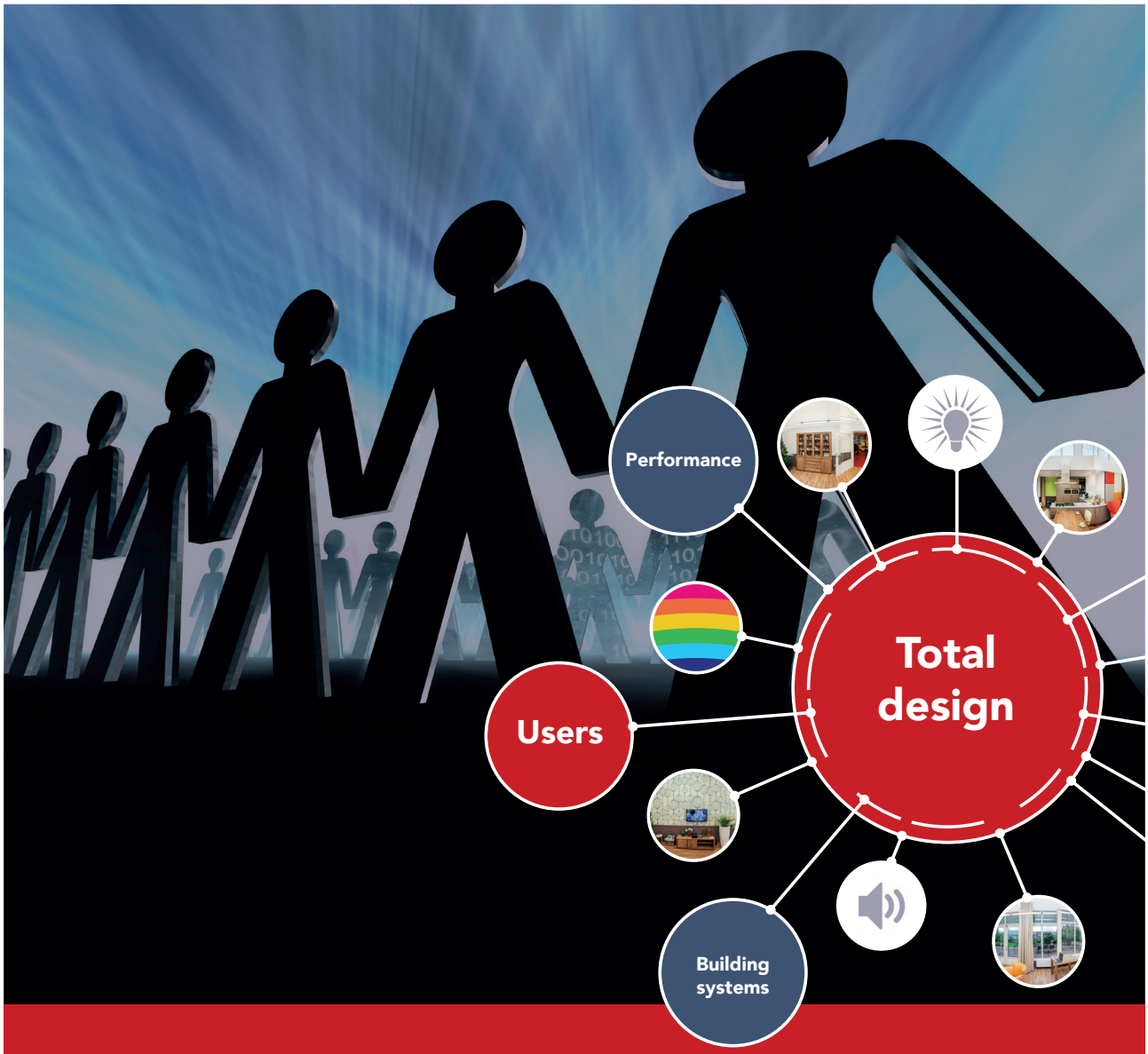
A user-oriented focus to create healthcare facilities; decision making on strategic values



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Emelieke Huisman

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PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven,
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door

Emilia Rosalia Catharina Maria Huisman

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Het onderzoek of ontwerp dat in dit proefschrift wordt beschreven is uitgevoerd in overeenstemming met de TU/e Gedragscode Wetenschapsbeoefening.

Contents

Summary

In our continuously growing and ageing society, the demand for healthcare facilities and personalised care increases. Different trends and developments are currently arising to face the challenges of the healthcare system to reduce the healthcare costs and enhance the quality of care. Consequently, the Dutch government changed its legislation from a publicly supported healthcare budget system into a regulated market system. This means that Dutch healthcare organisations are now financially responsible for the profits and risks of their real estate investments. As a result of this change, there is growing competition between healthcare providers. In addition, technological innovations (e.g. home automation), sustainability and the design of a healing environment have become increasingly important for Dutch healthcare building design.

Discussions about the importance of the built environment for the patient's health and well-being and the provision and support of healthcare extend at least as far back as 400 BC with Hippocrates and the 19th century with Florence Nightingale. Effects of the physical environment on the patient's healing process, recovery, and well-being have consequences for the design and construction of healthcare facilities. In the 1990s, design solutions in healthcare, based on published research, were defined as evidence based design (EBD). Evidence based design has become the theoretical concept for what is called 'Healing Environments'. Despite this attention, long-term care facilities, such as nursing homes, are not included in the majority of studies on 'Healing Environments'. Furthermore, the majority of these studies are written from the residents' perspective and rarely from the healthcare professionals' perspective or both. Also, it is important for long-term care organisations to present themselves as being focused on care with a physical environment that supports the quality of life of older people and the well-being of the healthcare professionals who take care of them.

New design approaches have been implemented in some long-term care facilities to ameliorate their environments and to cope with the innovations and trends. Designing long-term care facilities is a complex and dynamic process, especially when it involves multiple user groups and stakeholder groups with complex demands, such as older people with psychogeriatric disorders. In addition, the organisation and design team have to translate the evidence-based design findings from hospital studies into design solutions that are beneficial for long-term care organisations. This requires a better understanding of the various needs regarding the built environment of long-term care facilities. For decision-makers, it is useful to develop a bottom-up approach with a user-oriented focus to

implement the various needs in an accommodation strategy. Therefore, the aim of this thesis is: "*To gain a better understanding of the decision-making process of an accommodation strategy for nursing home organisations with a user-oriented focus and a bottom-up approach. This in order to contribute to support healthcare professionals in their work environment and to create an indoor environment suitable for frail older people needs and desires*".

A literature review **(Chapter 2)** was performed to provide an overview of the evidence in the literature on the healing environments concept from the perspective of the needs of multiple user groups. This review surveys and structures the scientific research on evidence-based healthcare design. As a result, this thesis focusses on the indoor environmental aspects light, acoustics, and indoor air quality that influence the quality of life of residents and the well-being of healthcare professionals through describing the decision-making process of nursing home real estate decisions.

Chapter 3 presents a framework for a structural approach for a decision-making process to help to create enriched small-scale care facilities for older people with a frail health condition. The focus of this study was placed on redesigning a common living room of a small-scale care facility by using the perspective of the different stakeholders via a participatory design approach. The structural approach identifies key factors (such as shared language, collective understanding and involvement of user groups) that should be considered when developing healthcare facilities and describes the critical steps for decision-makers for such environment. This case study provides a rich source of information from actual experiences for a better understanding of steering mechanisms for decision-making by the management of small-scale care facilities.

Chapter 4 reports two experiments and one exploratory study that examine the indoor environmental factors light, acoustics and indoor air quality in a common living room of a long-term care facility. The results of the first study show a significant improvement of the lighting conditions in illuminance and Correlated Colour Temperature values. In the second study, the results show a decrease of 50% in reverberation time and a 0.12 increase of the speech transmission index (STI). The healthcare professionals remarked that they felt more comfortable and less tired. According to the professionals, the residents seemed more comfortable in the living room. Insight in different user experiences creates the possibility to obtain a better understanding of the consequences of design decisions for the primary process of care giving. In the third study an approach for the building assessment has been developed from the perspective of indoor air quality and its effect on the spread of airborne infectious diseases. From this study, it can be concluded that this method has potential to

evaluate, compare long-term care facilities and develop design guidelines for these buildings.

After these studies, this thesis contine to investigate the underlying motives and values that drive board and management, as decision-makers, for the nursing home real estate they manage **(Chapter 5)**. The results of the study provides detailed mental representations of real estate decisions by nursing homes decision-makers. The findings show that nursing home decision-makers strive for an attractive and inspiring environment. Therefore, besides financial aspects, the values 'increase satisfaction', 'enhance quality of life' and 'participation' were highly appreciated benefits.

In conclusion, this thesis shows a structural approach that takes into account the needs of the multiple user groups (residents, healthcare professionals and decision-makers) in the planning and design. Overall, this dissertation provided a deeper understanding of users' need and the effects of the indoor environmental factors on residents and healthcare professionals from the perspective of corporate real estate management (CREM). It opens up various new directions for future research in the area of healthcare, corporate real estate management and decision-making.

Samenvatting

In onze continu groeiende en vergrijzende samenleving neemt de vraag naar plekken in zorginstellingen en gepersonaliseerde zorg toe. Dit gaat gepaard met uitdagingen voor de Nederlandse gezondheidszorg. Verschillende trends en ontwikkelingen worden geïntroduceerd om de zorgkosten te verlagen en de kwaliteit van de zorg te verbeteren. Hierop heeft de Nederlandse overheid haar wetgeving veranderd van een door de overheid ondersteund budgetsysteem (aanbodsturing) in een gereguleerd marktsysteem. Dit betekent onder andere dat zorgorganisaties zorg dragen voor de winsten en risico's van de eigen vastgoedinvesteringen. Dit leidt onder andere tot een toenemende concurrentie tussen zorgaanbieders. Ook de komst van technologische innovaties (zoals domotica), duurzaamheid en concepten als een 'Healing Environment' hebben impact op het ontwerpen van zorggebouwen.

Discussies over het belang van de gebouwde omgeving voor de gezondheid en het welzijn van de patiënt en de ondersteunende rol voor de gezondheidszorg gaat terug tot 400 voor Christus met Hippocrates en de 19e eeuw met Florence Nightingale. Effecten van de fysieke omgeving op het genezingsproces, herstel en welzijn van de patiënt hebben gevolgen voor het ontwerp en de bouw van zorginstellingen. In de jaren negentig werden ontwerpoplossingen in de gezondheidszorg, gebaseerd op wetenschappelijk onderzoek, gedefinieerd als 'Evidence-Based Design' (EBD). Het 'Evidence-Based Design' is het theoretische concept geworden voor wat 'Healing Environment' wordt genoemd. Ondanks deze aandacht zijn verzorgingshuizen niet opgenomen in de meeste onderzoeken naar 'Healing Environment'. Bovendien zijn de onderzoeken meestal geschreven vanuit het perspectief van de cliënten en beperkt vanuit het perspectief van de zorgverleners of beide. Bovendien willen zorgorganisaties zichzelf presenteren als een organisatie die er naar streeft dat het welbevinden mede bevorderd wordt door het gebouw en dat zorgprofessionals een prettig werkklimaat ervaren, waardoor dit bijdraagt aan de kwaliteit van zorg.

Om met deze innovaties en trends om te gaan, implementeren zorgorganisaties nieuwe ontwerp-strategieën die er op gericht zijn de fysieke gebouwde omgeving in te zetten zodat het welzijn van de gebruikers bevorderd wordt. Het ontwerpen van zorggebouwen is een complex en dynamisch proces, vooral als het gaat om stakeholdergroepen met complexe eisen, zoals bijvoorbeeld ouderen met psychogeriatrische aandoeningen. Bovendien zullen de zorgorganisatie en het ontwerpteam samen de uitkomsten vanuit de ziekenhuisstudies, gericht op 'Evidence-Based Design' en het 'Healing Environment'- concept, moeten vertalen naar ontwerpoplossingen voor een gebouwopzet en inrichting die gunstig zijn voor

zorginstellingen. Dit vraagt een beter begrip van de verschillende behoeften met betrekking tot de gebouwde omgeving van zorginstellingen. Voor het bestuur en management van zorgorganisaties is het nuttig om een bottom-up benadering te ontwikkelen met een gebruikersgerichte focus om de verschillende behoeften in kaart te brengen en te vertalen naar gebouwopzet, het ontwerp en de inrichting. Daarom is het doel van dit proefschrift: "*Een beter begrip krijgen van het besluitvormingsproces om tot een huisvestingsstrategie te komen voor zorgorganisaties. Dit met een gebruikersgerichte focus en een bottom-up benadering om bij te dragen aan het werkklimaat van zorgprofessionals en om een omgeving te ontwerpen die geschikt is voor de behoeften en wensen van kwetsbare ouderen* ".

Een literatuuronderzoek **(hoofdstuk 2)** is uitgevoerd om een overzicht te geven welke prestaties al bewezen zijn en welke prestaties nog ter discussie staan binnen het 'healing environment' concept. Het literatuuronderzoek onderscheidt en structureert uitkomsten uit wetenschappelijke studies naar (bouw) eisen van belang voor zorgprofessionals en van belang voor patiënten. Hieruit volgend richt dit proefschrift zich op het besluitvormingsproces van huisvestingsbeslissingen in zorgorganisaties door de binnenmilieuaspecten licht, akoestiek en binnenluchtkwaliteit te onderzoeken.

Hoofdstuk 3 beschrijft een raamwerk voor een gestructureerde aanpak voor een besluitvormingsproces om tot een ontwerp te komen die bijdraagt aan het welzijn van kwetsbare ouderen. De focus van dit onderzoek ligt op het herinrichten van een gemeenschappelijke woonkamer van een zorginstelling met kleinschalig wonen. Centraal in de gestructureerde aanpak staat het betrekken van verschillende stakeholdergroepen, door middel van participatory design, in het ontwerp en ontwikkelproces. Het hoofdstuk sluit af met aantal factoren (zoals dezelfde taal spreken, draagvlak bij en betrokkenheid van belanghebbenden) waar rekening mee gehouden kan worden bij het ontwerpen van het gebouwopzet en inrichting van zorginstellingen door het bestuur en management van zorgorganisaties. Tot slot, het raamwerk draagt bij aan een beter inzicht van de kritische stappen en mogelijke sturingsmechanismen voor het nemen van huisvestingsbeslissingen.

Op basis van de structurele aanpak in hoofdstuk drie, worden er in **hoofdstuk 4** de uitkomsten van twee experimenten en één verkennend onderzoek beschreven. In drie verschillende studies zijn de binnenmilieuaspecten licht, akoestiek en binnenluchtkwaliteit in een gemeenschappelijke woonkamer van een zorgorganisatie onderzocht die is aangepast. De resultaten van de eerste studie tonen een significante verbetering van de lichtcondities in verlichtingssterkte en kleurtemperatuur. In het tweede onderzoek tonen de resultaten een afname van 50% in nagalmtijd en een toename van 0,12 van de spraakoverdrachtsindex (STI). Uit de interviews met de zorgprofessionals blijkt dat zij zich

prettiger en minder moe voelden. Daarnaast merkten de zorgprofessionals op dat de bewoners meer op hun gemak waren in de aangepaste woonkamer. Deze gebruikerservaringen geven een beter inzicht in de gevolgen van ontwerpbeslissingen voor het primaire zorgproces. In het derde verkennend onderzoek is een aanzet voor een structurele aanpak ontwikkeld om gebouw karakteristieken, Heating, Ventilation and Air Conditioning systems (HVAC), binnenlucht kwaliteit, de uitbraak van infectieziekten en het welbevinden te kunnen beoordelen. Uit deze studie kan worden geconcludeerd dat de methode de mogelijkheid biedt om de gebouweigenschappen van zorginstellingen te evalueren, te rangschikken en te vergelijken om inzicht te krijgen in de kwaliteit van het gebouw en de impact op comfort en gezondheid.

Hoofdstuk 5 gaat dieper in op de onderliggende motieven en waarden die het bestuur en management, als beslissingsnemers, hebben voor het zorgvastgoed dat zij beheren. De resultaten van het onderzoek geven weer welke overwegingen de beslissingsnemers nemen om de waarden te bereiken die zij voor ogen hebben met de vastgoedportefeuille. De bevindingen tonen aan dat het bestuur en management van zorgorganisaties streven naar een aantrekkelijke en inspirerende zorgomgeving. Dit blijkt uit de resultaten die aangeven dat naast financiële aspecten, de waarden tevredenheid, verbeteren van de kwaliteit van leven en participatie toegevoegde waarden zijn bij het nemen van huisvestingsbeslissingen.

Samenvattend laat dit proefschrift zien hoe een gestructureerde aanpak de behoeften van de verschillende gebruikersgroepen (bewoners, zorgprofessionals en beslissingsnemers) kan meenemen bij de planning en het ontwerp van een zorggebouw. Daarnaast geeft dit proefschrift een beter inzicht van de impact van binnenmilieufactoren op bewoners en zorgprofessionals vanuit het perspectief van Corporate Real Estate Management. Het opent verschillende nieuwe richtingen voor toekomstig onderzoek op het gebied van gezondheidszorg, strategisch huisvestingsmanagement en besluitvorming.

Chapter 1

General Introduction

1.1 Introduction

In our continuously growing and ageing society the demand for healthcare facilities and personalised care increases. Furthermore, the current healthcare landscape is characterised by the development of technical and medical innovations which led to new opportunities for care and cure (Kort, 2012; van der Zwart, 2014). This all will result in a rise in healthcare costs. Although healthcare is expensive, it is also valuable for the quality of life in an ageing society. In this section the different trends and developments are described which are currently arising to face the challenges of the healthcare system in order to reduce the healthcare costs and enhance the quality of care. First, new visions on care delivery are discussed. Next, the developments in healthcare real estate investment and health in relation to the built environment are introduced.

1.1.1 Care delivery

The aim of care delivery should to be foster optimal health outcomes by providing cost-effective care and puts the patient at the center of the care provided (van der Eijk *et al.,* 2013; Richards, 2011; Bauman *et al.*, 2003). An important trend is that the focus of healthcare facilities is in transition from the manner of care delivery (the process of care) to the effect of care on clients (the outcomes of care) (Garre-Olmo *et al.,* 2012). The shift to patient-centred care, also referred to as "culture change" can be traced back to the 19th century with Florence Nightingale (1859), and it involved a change from an emphasis on safety, uniformity and medical concerns to client-directed health promotion and quality of life by considering the physical care environment (Ulrich, 1984). Studies showed that the physical care environment affects patient's satisfaction and enhances the quality of life during their stay in healthcare facilities (Ulrich *et al.,* 2004; Ulrich *et al.,* 2008). The current challenge is to establish an integrated design system, in which both the needs of patients and healthcare professionals as well as the built environment are considered equally important in design of healthcare facilities. Therefore, this research focusses on how different users of healthcare facilities can participate in the design process of healthcare facilities.

1.1.2 Healthcare real estate investment

In the Netherlands, there used to be a centrally directed budget system of healthcare real estate investment. However, the Dutch government changed this legislation (2008) into a regulated market system to keep healthcare affordable in the future (van der Zwart, 2011). This resulted in that today Dutch healthcare organisations are responsible for the profit and risks of their real estate investments, whereas in the old budget system all capital costs were

financed by the Dutch government (van der Zwart and Van der Voordt, 2016). The aim of this transition in legislation was to stimulate competition and improve healthcare but with lower costs. As a result, the significance of a healthcare organisation's real estate strategy has increased and the position of healthcare real estate has therefore changed rapidly over the last decade (van der Zwart. 2011).

The described developments changed the way healthcare organisations manage their real estate, choose their locations and decide on their buildings. In addition, these rapid changes are responsible for more competition in the healthcare sector (Appel-Meulenbroek *et al.,* 2010). The changing context creates opportunities but also new risks for the healthcare organisations. The corporate real estate management (CREM) of Dutch healthcare organisations is shifting to managing real estate as a strategic resource. The goal of this shift is that real estate should add value to the organisation like other resources such as, Human Resource Management, and technology (Joroff, 1993). CREM needs to align their strategy and activities to corporate strategy during the entire process that the organisation runs through. Along the way, many different matters need to be considered and tools need to be used to help make the right decisions. Since companies can follow many different corporate strategies, achieving alignment means choosing an adequate Corporate Real Estate (CRE) strategy to help support corporate goals.

1.1.3 Health and the built environment

Another trend is the growing interest in the role of technology and the built environment as part of the holistic treatment of patients. Environmental factors have become more important in the current therapeutic approach of patients or residents. A growing body of research in evidence-based design (EBD) demonstrates that elements of the physical environment correlate with health-related outcomes (Bosch *et al.,* 2011). For example, the physical and social environment of healthcare facilities can have a positive impact on the quality of life of people who suffer from dementia (van Hoof *et al.,* 2010; Hayne and Fleming, 2014). Also, indoor air quality, quality of acoustical climate and lighting conditions are mentioned as environmental factors which contribute to healthcare outcomes (Garre-Olmo *et al.,* 2012). Indoor air quality is associated with health problems (Brugha *et al.,* 2014; Marmor, 1978) and air can also transfer airborne infection diseases (Li *et al.,* 2007). High levels of sound are associated with less interaction between e.g. the healthcare professional and resident and visual discomfort symptoms are related to impaired reading performance, headaches and light sensitivity (van Duijnhoven, et al., 2019; Garre-Olmo *et al.,* 2012). For the latter correlated colour temperature (CCT) and illuminance levels are two important characteristics of light to be considered with regards to human perception (Shamsul *et al.,* 2013). CCT supports and enhances the impact of lighting on users (Sanaz,

2011). On the other hand, the use of inappropriate CCT of light has negative effects on human health, such as eye strain or negative emotional and circadian effects (Tilborg, 2017; Kort, 2017). These potential negative effects of the physical environment on the overall outcome for patient centred care, i.e. healing and well-being, are key factors to take into account when designing and constructing healthcare facilities.

To integrate the environmental factors as part of the holistic approach for care delivery, some healthcare organisations are already implementing concepts around healthy environment (HE), such as the 'Healing Environment' concept, Mayo clinic, Eden Alternative and Life Enrichment Care (Kort, 2012). A key component in these concepts is the possibility to create an environment which positively affects the client's well-being and cure/healing. The current challenge is the complexity of the decision making process and deciding which aspects of the physical environment should be implemented in the care environment to reach the aim of the HE concepts. The choices involved in the design decision-making process are often interrelated and allow many solutions with outcomes that might be hard to predict.

1.2 Users of healthcare facilities

The focus of this research is on long-term care facilities and their main users. There is a broad spectrum of long-term care, such as nursing homes, assisted living facilities and rehabilitation centres. Long-term care facilities provide a variety of services to people who are unable to participate independently in society. The main users include the residents and healthcare professionals. Residents in long-term care facilities are often frail and suffer from one or more chronic diseases. Due to their performance status and the functional decline they experience a progressive inability to be self-reliant in their own living environment. The majority of the residents in long-term care facilities are suffering from late-stage dementia and become dependent on their care providers (Verbeek *et al.,* 2010). Dementia is an overall term used to describe a syndrome associated with more than 100 different diseases that are characterised by the impairment of brain functions, including language, memory, perception, personality and cognitive skills (Hayne and Fleming, 2014).

Older people suffering from dementia have different needs concerning their environmental factors (Kort, 2017). Appropriate design of a long-term care facility can incorporate environmental modifications that may help to compensate for functional deficits in older people with dementia. For example, older people suffering from dementia often have impairments such as reduced vision and hearing loss, which compromises their ability to participate in activities requiring certain levels of sound and light for optimal engagement

(Hayne and Fleming, 2014).

A long-term care facility is not only an environment in which care is delivered and where people live, it also a work environment for the healthcare professionals providing the care needed. Healthcare professionals in long-term care facilities work in challenging and stressful conditions. The indoor environmental quality could attract and retain healthcare professionals and enhance their productivity and efficiency (Nimlyat and Kandar, 2015). However, poor indoor environmental quality (e.g. lighting, acoustical climate and indoor air quality) can cause serious health outcomes such as stress (Rashid and Zimring, 2008). This all may affect job performance, satisfaction and the quality of care. Therefore, a comfortable, safe and pleasant work environment is required to provide a high quality of care and to attract healthcare professionals. Identifying the needs regarding the physical environment of healthcare professionals is an important input for the design of a decision-making process of long-term care facilities.

Although it is known how the physical built environment correlates with health-related outcomes and the impact on quality of life of older people, it is still unknown how these needs are integrated in the design decision-making of long-term care facilities. The current care environment is a complex system, in which multiple user groups, such as healthcare professionals, residents, and facility staff, live and work together, all with different demands for their (ideal) environment. The users' satisfaction is determined by all environmental factors in the building system. Due to the variety of demands of its users, it is a challenging environment to design. A solid design strategy to address these conflicting users' needs may be (a part of) the solution.

1.3 Real estate decision-making

Decisions about the built environment in long-term care facilities are made by the board members or real estate managers (nursing home decision-makers). For the nursing home decision-makers it is a challenge to integrate the different needs of all stakeholders in a real estate strategy for the healthcare organisation. The nursing home decision makers are the facilitators in the translation of the users' needs into the real estate strategy. Therefore, a shared common language is important. Participatory methods are often used for user involvement in product design processes. Previous studies showed that participatory design methods can improve the understanding and the relation between the user and designer or decision-makers (e.g. Vagn *et al.,* 2016; Simonsen and Hertzum, 2012). For example, nowadays mock up evaluation of design prototypes is becoming a common practice in architectural projects related to healthcare (Traversari *et al.,* 2013; Peavey *et al.,* 2012).

These mock-ups can be used in the strategic design process to obtain critical feedback from end-users and support the development of a shared common language between designers and users.

Real estate decisions regard long-term planning and include the entire building cycle process. Furthermore, if organisations want to add value with real estate, they have to align real estate decisions with core business strategies. This includes different levels, from strategic (e.g. vision) to operational (e.g. facility) level and consideration of basic issues such as "what is the contribution of real estate to the function of the business" (Nourse and Roulac, 1993). To find solutions, there is a need for mental representations (MR) of the decision problem that explicates the variables judged for evaluation of these choices (Arentze, *et al.,* 2008).

The changes in the Dutch healthcare system as described in Chapter 1.1.2 lead to modifications in how to accommodate organisations, their (healthcare) professionals and clients. This asks more responsibilities for Corporate Real Estate (CRE) Managers. Besides the changes in the Dutch Healthcare system, there are also other trends currently arising in the field of CRE research. One important trend refers to the shift from cost minimisation to value delivery and the transition in focus from buildings to people (Jylhä *et al.,* 2019). However, the relationship between corporate real estate and organisational strategy in order to deliver organisational value is still an issue for CREM (Heywood and Arkesteijn, 2017). Generating this added value is a challenge as decision-makers indicate that it is difficult to achieve alignment (Heywood, 2011).

Table 1.1 shows a comparison of different lists of strategic added values of real estate (strategies) developed over time. These values and strategies have been rephrased and new additional values or context related values were introduced (Den Heijer, 2011). In the past years more people-oriented values, such as ***'improving quality of place', 'support culture'*** and ***'stimulation collaboration'***, were added to list of strategic added values of real estate. Whereas in the study of De Jonge (1996) the focus was on cost reduction and increasing the value of assets. In the most recent study of Van der Voordt (2016) other specific care sector values such as creating a ***healing environment*** and ***sustainability*** (see Table 1.1, in bold and italic) were added. Supporting innovation, increasing user satisfaction and improving the organisation's culture were already identified as highly appreciated values within the hospital environment by decision-makers (Van der Zwart, 2011).

Table 1.1: Comparison of different lists of added value of real estate and real estate strategies developed over time.

Van der Voordt 2016	Riratanaphong and van der Voordt, 2015 based on Bradley 2002	Van der Zwart 2014	Den Heijer 2011	Lindholm 2008	De Jonge 1996
Adding value by health care real estate	**performance measures**	**Added value hospital real estate**	**Added value of real estate**	**Real estate strategies**	**Added value of CRE**
Cost reduction	Cost efficiency	Cost reduction	Decreasing costs	Reduce costs	Reduce costs
Productivity	Productivity	Productivity	Supporting user activities	Increase productivity	Not mentioned
User satisfaction	Stakeholder perception/ employee perception	User satisfaction	Increasing (user) satisfaction	Increase employee satisfaction	Not mentioned
Not mentioned		Not mentioned	***Improving quality of place***	Not mentioned	Not mentioned
Innovation	Organisational development	Innovation	Stimulation innovation	Increase innovation	Not mentioned
Flexibility		Flexibility	Increase flexibility	Increase flexibility	Increasing flexibility
Not mentioned		Culture	***Supporting culture***	Not mentioned	Improve culture
Not mentioned		Not mentioned	***Stimulation collaboration***	Not mentioned	Not mentioned
Postive image		Positive image	Supporting image	Promoting marketing and sale	Marketing
Risk control		Risk control	Controlling risk	Not mentioned	Risk management
Healing environment		Not mentioned	Not mentioned	Not mentioned	Not mentioned
Opportunities to finan	Financial health	Finance opportunities	Increase real estate value	Increase value of assets	Increase the value of assest
Sustainability	Environmental responsibility	Not mentioned	Reducing ecological footprint	Not mentioned	Not mentioned

Identifying which added values and how these are incorporated in the decision-making process of nursing home real estate is an important step to develop strategic values for decision-makers in healthcare real estate.

1.4 Research gap and aim of the thesis

Real estate is a costly resource for organisations (Appel-Meulenbroek *et al.,* 2013). However, there still is a lack of knowledge of CREM decisions about real estate with an overall strategy in mind (Appel-Meulenbroek *et al.,* 2013). To understand the strategic decision-making process of real estate and the alignment with the corporate strategy, insight into the **underlying motives** behind real estate decisions by decision-makers is required.

Due to the changes in the budgetary system of the healthcare sector, real estate has become more important as a management field for this sector as well. Therefore, the corporate real estate management (CREM) of Dutch healthcare organisations is shifting to managing real estate as a strategic resource and to include people-oriented values. This means according to Jensen *et al.,* (2012) quality in relation to the needs and preferences of users. However, it is still unknown how decisions are made by board and managers in nursing home settings and how they take into account people-oriented values.

Therefore, in this thesis, the strategic decision-making process in nursing homes setting is studied. But first the understanding of **building users' perception of design factors** is examined, because it is essential for informed **decision-making** during early design stages since they have the deepest knowledge of the work processes (Reijula, *et al.,* 2014). Users

should also be structurally involved in the design of the facility. Understanding of building users' perception is also important for implementing concepts around healthy environments (e.g healing environment, Mayo Clinic, Eden Alternative and Life Enrichment Care). There is a lot of research how the physical environment can contribute to human health and well-being, but there is insufficient knowledge about decision-making on strategic values in relation to the interaction of the building users with the physical environment. Users' satisfaction depends on real estate and facilities decisions regarding design and environmental quality (Ramakers, 2008). In line with the growing attention for healthy environments, designers, architects and decisions-makers try to create a space that enhances employees' flow of work as well as their perception of physical and psychological well-being (Reijula, *et al.,* 2014). **User-oriented and participatory** approaches have exhibited vast potential in creating these spaces. The primary objectives for a participatory and user-oriented approach are to increase users' well-being and satisfaction (Reijula, *et al.,* 2014).

So far, the influence of the physical environment on human health is mainly focused on hospital environments. These studies have demonstrated that the physical environment and social environment of hospitals contributed to health outcomes (e.g. Ulrich *et al.,* 2008), which underlines the likelihood that the built environment affects recovery and well-being in a care setting too. However, these studies mainly focused on patient outcomes, while literature about healthcare professionals outcomes is still limited. On the contrary, the physical environment and how this affects employees comfort and well-being is extensively studied in the office sector (Roelofsen, 2002; Vimalanathan and Babu, 2014). Less is known about how environmental factors in nursing home settings affects healthcare professionals and residents.

To measure health outcomes regarding design decisions and how these decisions influence the users' perception is complex. Zhang *et al.,* (2019) provided an environment – occupant – health (EOH) -framework (see Figure 1.1) that offers an approach for a more effective comparison between different design solutions. This framework incorporates the interactive effect of various environmental factors. It resembles the importance of a holistic approach which considers the environmental factors taking together and not separately. It can be compared with the WHO framework for the International Classification of Functions and disabilities (ICF) (WHO, 2002). In ICF clear pathways are given about how contextual factors (including the building physical factors) influence health. The contextual factors of the ICF model include the lighting conditions, the acoustics, air quality, thermal comfort, humidity and information technology.

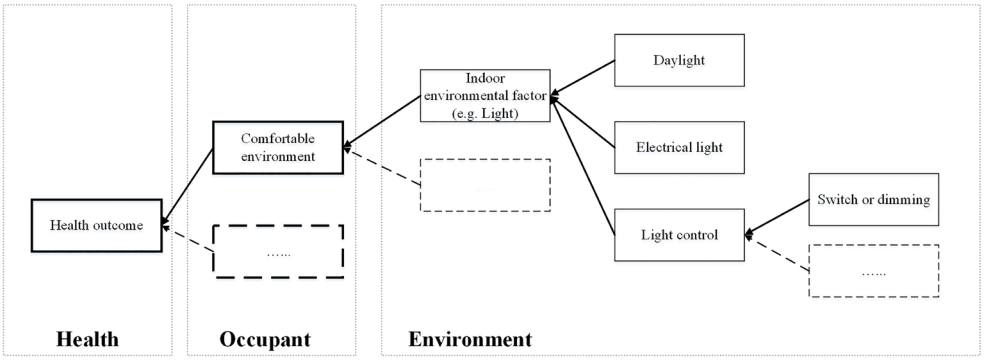

Figure 1.1. Structure of the Environment-Occupant-Health (E-O-H) framework by Zhang *et al.,* 2019

However, there is still a lack of a holistic approach as well of tools and methods for the implementation of design decisions in order to support decision-makers. This requires a better understanding of the various needs regarding the built environment of healthcare facilities. For decision-makers, it is useful to develop a bottom-up approach with a user-oriented focus to implement the various needs. Therefore, the aim of this research is:

To gain a better understanding of the decision-making process of an accommodation strategy for nursing home organisations with a user-oriented focus and a bottom-up approach. This in order to contribute to support healthcare professionals in their work environment and to create an indoor environment suitable for frail older people needs and desires.

To achieve this aim, the following research questions will be examined:

- What is the influence of physical environmental factors on users of healthcare facilities?
- How can multiple user groups be successfully involved in the design decision-making process of healthcare facilities?
- How to create an indoor environment for multiple user groups (older people and healthcare professionals)?
- What are the underlying motives and values that drive decision-makers for the healthcare real estate they manage?

1.5 Research framework

The following section will outline the research design of this thesis. First, the new value adding management model (VAM) (van der Voordt *et al.,* 2016) will be discussed to explain the relationship between health and the built environment and support the decision-making process. Next, the research approach of this thesis will be discussed.

The new value adding management model (Voordt *et al.,* 2016) (see Figure 1.2) is introduced in order to support decision-makers in identifying appropriate interventions to add value to the organisation, to manage the implementation of the intervention and to measure the output and outcomes of the intervention. This model is based on Value Adding Management (VAM) (Jensen and van der Voordt, 2016) and the Plan-Do-Check-Act cycle (Deming, 1950). The cyclical character of this model shows that the process of adding value is a continuous process. The evaluation of the realised outcomes may be the starting point for new strategic plans and interventions. The VAM model starts with identifying why an intervention or new strategic plans are necessary and what conceptual choices regarding the physical environment or facilities are expected to optimise the corporate strategy. The integration of the Plan-Do-Check-Act cycle in the new VAM model will link the organisational objectives with facility management and CREM performance (van der Voordt *et al.,* 2016). This thesis follows several steps from this model to investigate how building design affects users' health and well-being based on the healing environment concept.

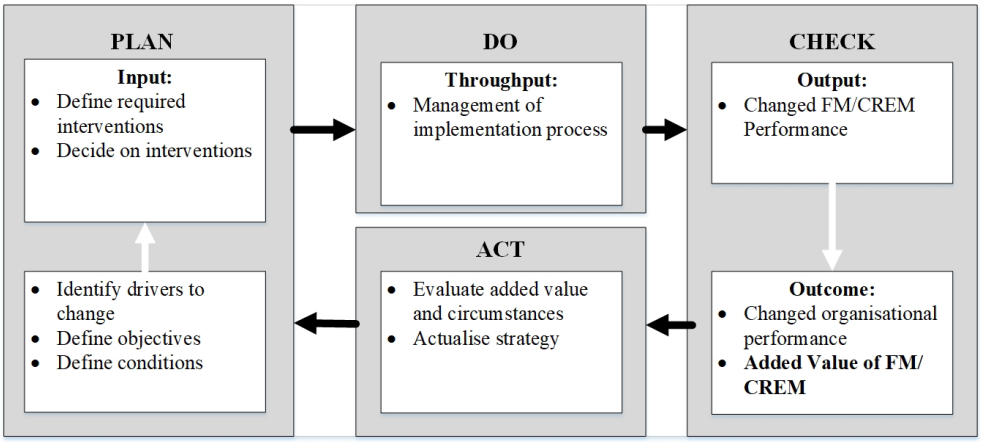

Figure 1.2: New Value Adding Management model by van der Voordt *et al.,* 2016

1.6 Research approach

The research approach of the thesis is visualised in Figure 1.3. A variety of methods were used in this thesis to describe the user-oriented focus and bottom-up approach. First, information on the healing environment concept in hospitals and their users (e.g. patients, family, and staff) is gathered through a literature review. This gives insight into the evidence on how the physical environment has an effect on the healing process and the well-being of multiple user groups. Furthermore, the literature review addresses relevant design features to take into account during the design decision-making process.

Next, a structural approach was developed to involve multiple user groups in the design decision-making process of a redesign of a common living room in a long-term care facility. The development of this structural approach is based on a participatory approach. It gives more insight into the critical steps in the design decision-making process of a long-term care facility. In addition, data is collected on the needs of the multiple user groups in a long term care facility regarding the indoor environmental factors of light, acoustics and indoor air by means of interviews, observations and indoor environmental measurements. This data is used to analyse and to develop interventions for the light conditions and acoustical climate for a long-term care facility and to develop a systematic approach with the purpose to analyse the relation between the indoor air quality and the outbreaks of infectious diseases.

Last, the laddering technique is used to describe the underlying motives and benefits of nursing home decision-makers regarding real estate. Finally, the findings of the different studies in this thesis are discussed from the perspective of the VAM model (van der Voordt *et al.,* 2016) in order to support nursing home decision-makers.

The next section describes the outline of the thesis.

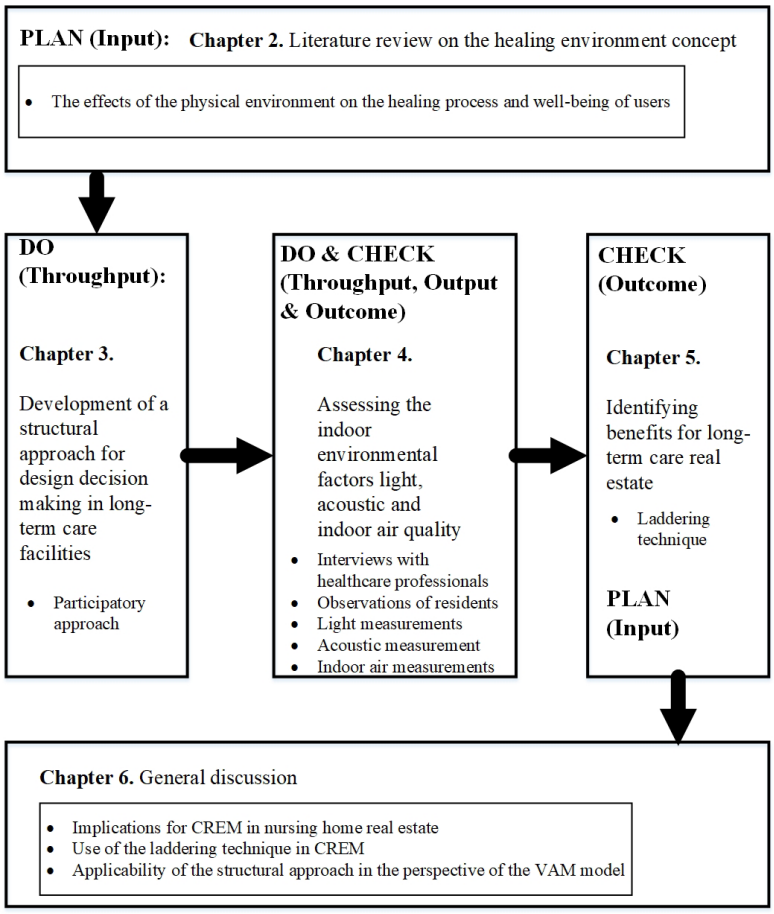

Figure 1.3. Research approach in the perspective of the VAM model (van der Voordt, *et al.,* 2016)

1.7 Outline of the thesis

A literature review (**Chapter 2**) was performed to determine the current status of research in the field of healing environments concepts from the perspective of the needs of multiple user groups. This review structures the scientific research on evidence-based healthcare design. **Chapter 3** presents a framework for a structural approach for a decision-making process to help to create enriched small-scale care facilities for older people with a frail health condition. The focus of this study was placed on redesigning a common living room of a small-scale care facility by using the perspective of the different stakeholders via a participatory design approach.

Following the approach in **Chapter 3**, three studies were conducted to investigate the indoor environmental factors light, acoustic and indoor air quality in a common living room of a long-term care facility (**Chapter 4)**. After these three studies, this research continues to investigate the underlying motives and values that drive board and management, as decision-makers, for the nursing home real estate they manage **(Chapter 5)**. The results of the study provided detailed models of real estate decisions by nursing homes decision-makers.

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Chapter 2

Healing environment: A state of the art

Huisman, E.R.C.M., Morales, E., van Hoof, J., Kort, H.S.M. (2012), "Healing Environment: A review of the impact of physical environmental factors on users", *Building and Environment*, Vol. 58, pp. 70-80, Doi: 10.1016/j.buildenv.2012.06.016.

Abstract

In recent years, the effects of the physical environment on the healing process and well-being have proved to be increasingly relevant for patients and their families (PF) as well as for healthcare staff. The discussions focus on traditional and institutionally designed healthcare facilities (HCF) relative to the actual well-being of patients as an indicator of their health and recovery. This review investigates and structures the scientific research on an evidence-based healthcare design for PF and staff outcomes. Evidence-based design has become the theoretical concept for what are called healing environments. The results show the effects on PF and staff from the perspective of various aspects and dimensions of the physical environmental factors of HFC. A total of 798 papers were identified that fitted the inclusion criteria for this study. Of these, 65 articles were selected for review: fewer than 50% of these papers were classified with a high level of evidence, and 86% were included in the group of PF outcomes. This study demonstrates that evidence of staff outcomes is scarce and insufficiently substantiated. With the development of a more customer-oriented management approach to HCF, the implications of this review are relevant to the design and construction of HCF. Some design features to consider in future design and construction of HCF are single-patient rooms, identical rooms, and lighting. For future research, the main challenge will be to explore and specify staff needs and to integrate those needs into the built environment of HCF.

Keywords:

Evidence-based design; Healthcare facility; Building system; Hospital design and construction; Professional; Patient Safety

2.1 Introduction

Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO, 1948). Healthcare facilities (HCF) are places where patients with health conditions go for treatment, which is provided by specialists and other care professionals. In recent years, we see a growing interest in the role of technology and the built environment as part of the holistic treatment of patients. Discussions about the importance of the built environment for the patient's health and well-being and the provision and support of healthcare extend at least as far back as 400 BC (Codinhoto *et al.,* 2009) with Hippocrates and the 19th century with Florence Nightingale (Nightingale, 1859). Burge described the relationship between symptoms of the "Sick Building Syndrome" (SBS) and the indoor environment of buildings (Burge, 2004). The term SBS comprises a group of symptoms of unclear aetiology consisting of dry skin and symptoms related to mucous membranes, as in the eyes, nose, and throat, together with what are often called general symptoms of headache and lethargy (Burge, 2004). In an office setting, the symptoms of SBS can reduce productivity and increase absenteeism from work. Similar problems occur in other buildings, for instance, in HCF. These effects of the physical environment on the patient's healing process, recovery, and well-being have consequences for the design and construction of HCF. In the 1990s, design solutions in healthcare, based on published research, were defined as "evidence-based design" (EBD). Evidence-based design has become the theoretical concept for what are called healing environments. Healing environments can be considered as "smart investments" because they save money, increase staff efficiency, and reduce the hospital stay of the patient by making the stay less stressful (Ulrich, 1992). Based on the definitions of several academic researchers (Jonas and Chez, 2004; Ulrich *et al.,* 2004; Ulrich *et al.,* 2008; Devlin and Arneill, 2003), a healing environment can be defined as a place where the interaction between patient and staff produces positive health outcomes within the physical environment.

The movement towards EBD in healthcare started with Ulrich (Ulrich, 1984), who compared the positive effect of views of natural scenery on the recovery of patients from surgery to patients in similar conditions who were exposed to a view of a brick wall. Ulrich showed that in comparison with the wall-view group, the patients with the tree view had shorter postoperative hospital stays, had fewer negative evaluative comments from nurses, took fewer moderately strong and strong medication, and had slightly lower scores for minor postsurgical complications. Since then, the impact of the physical environment of the hospital on the well-being and health of the patient has received extensive academic attention. Consequently, this resulted in a creation of spaces considered to be healing environments. An increasing body of knowledge on evidence-based healthcare design has

become available, and the amount of information has grown rapidly in recent years.

This study surveys and structures the scientific research on evidence-based healthcare design from the perspective of the needs of end-users. The group of end-users is defined as patient, family (PF) and staff in this review. The perspectives of the designer or project developer are omitted from consideration in this review. Furthermore, this review distinguishes between empirical data and evidence-based data concerning the patient and staff health outcomes in hospital settings.

2.2 The review procedure

2.2.1 Aim

The aim of the review is to provide an overview of the evidence in the literature on healing environments. The hypothesis is that healing environments, through EBD, make hospitals less stressful and promote faster healing for patients and improve well-being for their families, as well as creating a pleasant, comfortable and safe work environment for staff (Ulrich *et al.,* 2004; Ulrich *et al.,* 2008). Therefore, the following questions are explored in this review:

(1) Which findings of research related to PF outcomes and staff outcomes of healthcare design are evidence based or scientifically proven or are not (sufficiently) proven?

(2) Which findings of research related to PF outcomes and staff outcomes of healthcare design are under discussion?

2.2.2 Search methods for identification studies

The Cochrane Methodology (Cochran Library, 2011) was used to search the data. Potentially relevant literature was identified through computerised searches. Pubmed [Medline], Jstor, and Scopus were the databases used to find relevant articles (Figure 1). The search was performed using the keywords *evidence-based design, hospital design, healthcare design, healthcare quality, outcomes, patient safety, staff safety, infection, h*and *washing, medical errors, falls, pain, sleep, stress, depression, confidentiality, social support, satisfaction, single rooms, noise, nature* and *daylight*. The search criteria were based on characteristics of the several groups in this study. A total of 54 keywords were used and categorised into four groups: PF, staff, (physical) environmental factors, and relevant authors (such as *Ulrich*, *Zimrich and Bosch, Devlin and Arneill*).

For a further and more specific search, a combination of keywords was used in the Pubmed and Scopus research databases. The following combinations of keywords were selected: *healing environments* AND *patient outcomes; healing environments* AND *sleep; "hospital design* and *construction" [Mesh]* AND *safety; "hospital design* and *construction" [Mesh]* AND *stress; "healing environments"* AND *stress; "healing environments"* AND *patient safety; "evidence-based design"* AND *stress; "evidence-based design"* AND *outcomes;* and *"evidence-based design"* AND *physical environment* and *hospital design.*

The screening process, shown in Figure 2.1, indicates the different selection stages. After eliminating duplicate articles, the remaining articles were examined for further selection. At the final stage, articles were selected that referred to the physical environment of HCF in their titles and abstracts. The references from the identified articles were verified to determine whether they would result in additional literature. Studies were rejected or accepted for further analysis based on the titles and abstracts and the incorporation of the characteristics in one of the four groups of PF, staff, environmental factors or relevant authors.

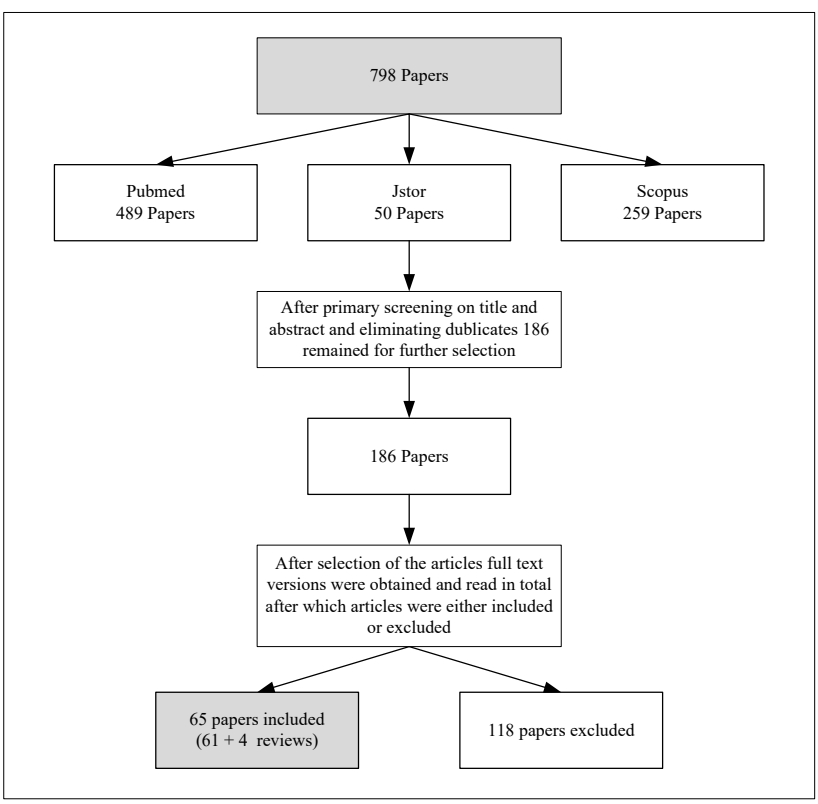

Figure 2.1. Flowchart of the screening process of the literature.

2.2.3 Theoretical approaches for healing environments

To order and structure the evidence regarding healing environments, the frameworks of integrated building design by Rutten (1996) and Ulrich *et al.* (2004; 2008) were used and adapted (Figure 2.2). This new framework can contribute to the understanding of all of the various aspects and dimensions that need to be taken into consideration throughout the process of designing and constructing new HCF. The framework describes a triangular relationship among the building system, the performance, and the users; each single element affects the other two. Within the framework, users are defined as PF, or staff. Within the framework, a building delivers performances that are among the user needs and are installed and fitted to meet those user needs; in turn, the building systems are translated to user outcomes (Figure 2). Each building system has a specific set of functions (which can be seen as solutions) that contribute to the optimisation of a particular user need. The success of the final design is the result of how well the needs of the stakeholders are met by the building systems.

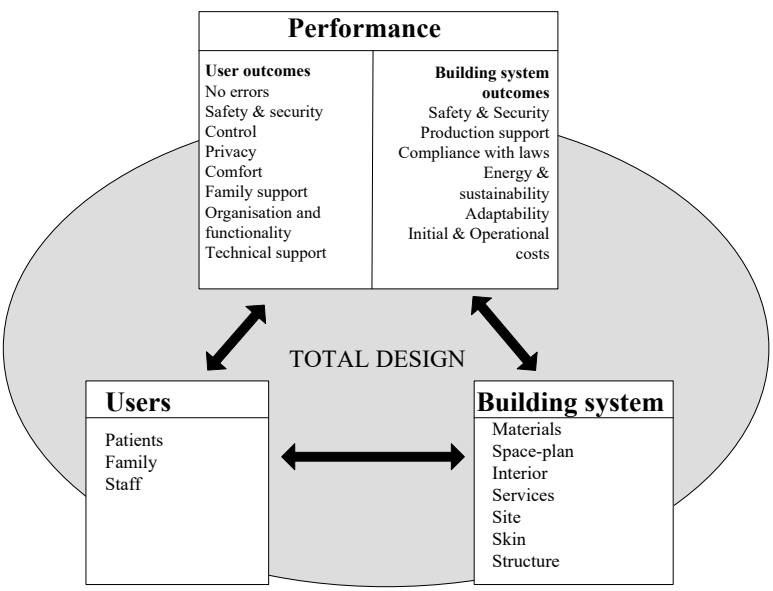

Figure 2.2. The framework of Integrated Building Design, based on the work of Rutten (1996) and Ulrich *et al.* (2004, 2008).

2.2.4 Inclusion and exclusion criteria

The screening process (Figure 2.1) is based on the following inclusion and exclusion criteria.

- Articles were limited to those published in English between 1984 and 2011. The start date was chosen based on Ulrich's 1984 publication addressing the effect of views of nature on patients.
- A cross-reference method was used for relevant literature outside the computerised searches. This also yielded papers older than the 1984 search limit. Consequently, relevant literature from 1960, 1970, 1976 and 1980 was included in this review.
- Articles were selected based on their references to the physical environment of HCF in the title and abstract.
- Articles were excluded that concerned aspects of medical treatment or wound healing.
- The title and abstract of the articles were rejected or accepted for further analysis based on the characteristics of the four groups.
- After selection of the articles, full-text versions were obtained and read in their entirety. The articles were either included or excluded based on the criteria that should be examined regarding the influence of environmental factors on PF and staff.

2.2.5 Analysis

The studies included in this review were further divided into two groups, PF outcomes and staff outcomes, by applying the so-called pyramid of evidence (Sackett *et al.,* 2000). Systematic reviews are at the top of the hierarchy, providing the richest source of the best evidence. Evidence obtained from randomised controlled trials (RCTs) (level four) is next, followed by evidence obtained from controlled trials without randomisation and from cohort studies and case-controlled studies (level three). Descriptive studies, evaluation studies, best practices, and qualitative studies are positioned at the base of the pyramid (level two). Agreement between the first and second authors and a third independent researcher was assessed using Cohen's Kappa (Landis and Koch, 1977).

The topics and subtopics chosen for this systematic review are based on topics as arranged in the literature reviews of Ulrich *et al.* (2004; 2008) (Figure 2.3).

Some relevant design features are addressed only at level two of the levels of evidence. In this review, only studies with level two or higher evidence are included for the analyses of the design features. Studies with a low evidence level are qualified with level one and are not included for further analyses of the design features.

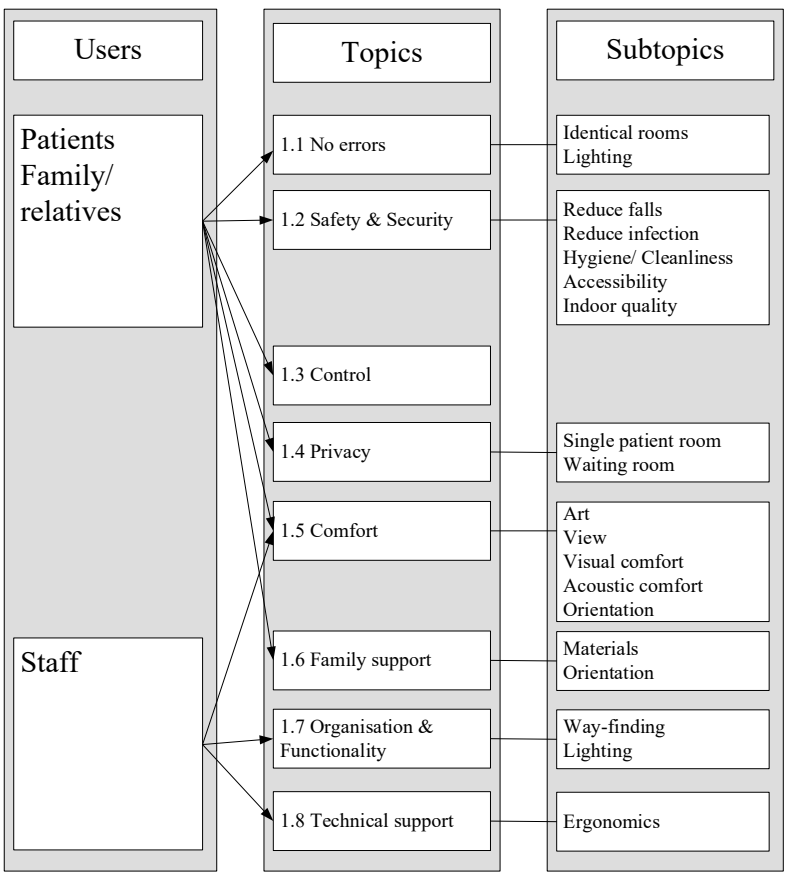

Figure 2.3. User perspectives classified in topics and subtopics based on literature reviews by Ulrich *et al.* (2004, 2008).

2.3 Results

The initial search strategy generated 798 papers. The first and second authors of this study evaluated the titles and abstracts, and a total of 798 papers were found to fit the inclusion criteria. Of these, 186 articles were included for further selection. After the final selection, 65 articles are included in the review and rated for four levels of evidence. The degree of reliability between the first and second authors and a third independent researcher had a value of 0.72. The value of 0.72 was considered a good level of agreement (beyond chance) for the level of evidence (Landis and Koch, 1977). Addressing the research questions of this review there were only 28 articles (fewer than 50%) classified as having a high level of evidence (Table 2.1). Most of these 28 fitted into the category of comfort, in particular, view and acoustic comfort. A distinction was made between PF outcomes and staff outcomes. Because these two user groups have different experiences with their built environments, they can have different beliefs regarding their surrounding environments and associate different meanings with them (Tanja-Dijkstra and Pieters, 2011). For instance, the patient visiting the hospital and the staff working at the hospital may not share the same experiences of their environment.

As a result of this review, 86% of the articles were included in the group of PF outcomes, and the other 14% of the identified articles fitted into the group of staff outcomes. Articles with a level two formed the majority of the studies in the staff category. Table 2.1 shows an overview of the included studies and their levels of evidence (Sackett *et al.,* 2000).

Table 2.1. Characteristics of the studies included and their level of evidence in the review for patients, family, and staff categorised by topics and subtopics.

	Topics	Subtopics	References and level of evidence	Total number of references	Lowest level of evidence	Highest level of evidence
Patient, Family (PF)	**No Errors**		[16]-2, [17]-2, [18]-3, [19]-3	4	2	3
	Safety and Security	Falls	[20]-2, [21]-2, [22]-2, [23]-2	4	2	2
		Infection	[24]-2, [25]-2, [26]-4, [27]-2, [28]-2, [29]-1, [30]-3, [31]-2	8	1	4
		Indoor Quality	[32]-2, [33]-3, [34]-3	3	2	3
	Enhancing control		[17]-2, [36]-1	2	1	2
	Privacy		[37]-3, [38]-2, [39]-2,	3	2	3
	Comfort	Comfort	**[7]-4 (review)**, [86]-1	2	1	4
		Materials	[27]-2, [40]-2	2	2	2
		Art	**[8]-4 (review), [90]-4 (review)**	2	4	4
		View	[10]-4, [42]-2, [44]-4, [45]-3; [46]-4, [47]-4, [48]-3, [49]-2	8	2	4
		Visual comfort	[50]-3, [51]-3	2	3	3
		Acoustic comfort	[55]-1, [56]-1, [57]-3, **[58]-4 (review)**, [59]-2, [60]-1, [61]-2, [62]-2, [63]-3, [64]-2, [65]-3	11	1	4
		Orientation	[52]-3, [53]-3, [63]-3, [67]-4, [68]-1, [74]-2	6	2	4
	Family support		[75]-2, [76]-2, [77]-2, [88]-2	4	2	2
Staff	**Organisation and functionality**		[74]-2, [79]-2, [7]-4	3	2	4
	Technical support		[80]-4, [81]-2, [82]-2, [83]-3, [84]-3	5	2	4
	Comfort		[85]-2	1	2	2

Level of evidence [9] 1= poor (expert opinion); 2= fair (case series, case reports); 3= good (cohort studies, case control studies); 4= excellent (randomised controlled trials, systematic reviews)

This section provides an overview of the current theoretical information related to healing environments concerning PF and staff outcomes.

2.3.1 Outcomes for patients and their families

In this section, the outcomes of healthcare design on PF were divided into the following main topics: no errors, safety and security, control, privacy, comfort and family support (Figure 3). All of these topics and their subtopics are addressed in this section.

Reduction of errors

One of the main concerns of patients is avoiding being subjected to human errors by staff and medical professionals working in a hospital. Two subtopics related to the physical environment in the category "no errors" can be distinguished, namely, identical rooms and lighting.

Identical rooms

The standardisation of patient rooms and equipment makes routine tasks simpler and decreases errors by staff. When the facility has identical rooms, the nursing staff encounter exactly the same distribution, layout and lighting in every room (Ulrich, 1991; Barnhart *et al.,* 1998). In addition, natural and electrical light is also an important aspect to consider for avoiding errors (Buchanan *et al.,* 1991).

Lighting

Several studies described the influence of lighting on errors. Booker and Roseman (1995) investigated the seasonal pattern of hospital medication errors in Alaska because 58% of all medication errors occurred during the first quarter of the year. Medication errors were 1.95 times more likely to occur in December than in September. In a similar article, although with the focus on electrical lighting, three different illumination levels were evaluated (480 lx, 1100 lx, 1570 lx). Buchanan *et al.* (1991) associated poor illumination with errors in dispensing medications. An illuminance of 1570 lx (the highest level) was associated with a significantly lower error rate (2.6%) than the 480 lx baseline level of 3.8%. There was a linear relationship between each pharmacist's error rate and that pharmacist's corresponding daily prescription workload for all three illuminance levels. Consequently, the rate of prescription-dispensing errors was associated with the level of illumination.

Summary of design features to address with a level of evidence of two or higher:

Identical rooms; lighting.

Increasing safety and *security*

This topic refers to all of the measures, interventions and elements that the hospital applies or has access to in order to increase the safety and security of their patients. The subtopics address reduced falls, reduced infections, improved hygiene and cleanliness, accessibility, and indoor quality.

Reduced falls

The subtopic of reduced falls describes the environmental influences in the hospital room that are related to patient falls. However, falls are often a result of an interaction between individual factors and environmental factors. For instance, Morgan *et al.* (1985) confirmed that there is a higher risk for patients admitted with a diagnosis of a mental disorder but there is no higher risk for those admitted with musculoskeletal problems or diseases of the central nervous system and sense organs. Falls were associated with activities requiring a change of posture (for instance, getting out of bed after having been in a recumbent position). Wong *et al.* (1981) and Morgan *et al.* (1985) explained that most falls occurred in the patients' room, mostly near the bed. Of the falls investigated, 29% occurred in the private bathroom attached to each patient room, and two-thirds of those occurred near the toilet. Of the 167 falls in the patient rooms, 57 occurred on the way to or from the bathroom. At least half of the total falls were bathroom-related, whereas in a similar study by Alcee (2000), only 30% were related to the bathroom.

Falls may be prevented with design features that consider the frailty of patients inside and outside their bathrooms. Once these basic features are corrected, patient falls can be decreased by up to 17.3% (Brandis, 1999).

Reduced infection rates

The subtopic of reduced infection rates explains how the design of the patient room can contribute to reduced contact spread. Infections and cleanliness are related to hygiene, which are, in turn, associated with the materials used in a hospital. It should be mentioned that many environmental surfaces and features become contaminated near infected patients, and personnel may subsequently contaminate their gloves by touching these contaminated surfaces (Boyce *et al.,* 1997; Aygun *et al.,* 2002). This manner of transmission is thought to be more common in multi-bed units. Examples of surfaces found to be contaminated frequently via contact with patients and staff include overbed tables, bed privacy curtains, computer keyboards, infusion pump buttons, door handles, bedside rails, blood pressure cuffs, chairs and other furniture, and countertops (Jonas and Chez, 2004). Anderson *et al.* (1982) found higher microorganism counts on carpeted floors than on bare floors. Further-

more, air above carpeting contained more consistent concentrations of organisms than air above the bare flooring. However, no difference was found in patients in a hospital room with carpet versus a room without carpet. Another study confirmed that contamination of carpeting was not associated with a significantly increased frequency of pseudomembranous enterocolitis infections (Skoutelis *et al.,* 1994). In addition to the fabric on floors, the fabric or upholstery of furniture can also be a reservoir for bacteria. Noskin *et al.* (2000) examined the contamination with vancomycin-resistant Enterocci (VRE) of fabric-covered furniture versus vinyl-covered furniture and vinyl surfaces. They showed that vinyl also became contaminated. However, routine disinfection was successful in removing VRE from vinyl surfaces, although not from fabric surfaces. In a similar study, Palmer (1999) investigated the bacterial contamination of curtains in clinical areas. In that case, the bed curtains had much higher counts of bacteria than the window curtains. In addition, ward bed curtains were a persistent source of contaminants and bacteria, including methicillin-resistant *Staphylococcus aureus* (MRSA).

It is common knowledge that the chances of infection by bacteria on hands are lower if hands are washed more often. Larson *et al.* (1991) discussed the effect of the use of an automated sink on the practice of hand washing and attitudes towards hygiene in high-risk units in two hospitals. Hands were washed better or more thoroughly but significantly less often using the automated sink.

In addition, the design of patient rooms can have an effect on the incidence of infections because tight corners are more difficult to clean than smooth edges. This may, in turn, have a negative effect on the performance of the building. In terms of logistics, McManus *et al.* (1992) compared common infections (*Pseudomonas aeruginosa)* and pneumonia (*Pseudomonus bacteremia)* in burn patients in single-bed rooms and in open wards. The study showed that single-bed rooms and good air quality substantially reduce infection incidence and reduce mortality.

Indoor quality

This subtopic encompasses elements such as ventilation, dust, smell, relative humidity, and air quality. A number of studies have focused on healing environments and ventilation. Smedbold *et al.* (2002), Arlet *et al.* (1989), and Panagopoulou *et al.* (2002) described the indoor quality related to the content of indoor air that could affect the health and comfort of building occupants and to the building materials, ventilation, and activities conducted in HCF.

Summary of design features related to safety and *security to address with a level of evidence of two or higher:*

No slippery floors, appropriate door openings, correct placement of rails and accessories, correct toilet and furniture height, single-bed rooms, easy-to-clean surfaces, automated sinks, and smooth edges in rooms.

Enhancing control

Providing a patient with a choice appears to be a key element in environmental psychology (Prochansky *et al.,* 1970). According to Ulrich (1991), the patient's lack of control is a major problem in hospital settings, which promotes stress and anxiety in patients. There seems to be a growing trend among some HCF to give patients more "control" over their environments (Ulrich, 1992; Birdsong and Leibrock, 1990).

Summary of design features related to enhancing control to address with a level of evidence of two or higher:

Self-supporting systems, such as control over the position of the bed, control over the temperature (air conditioning and heating), control over the lights (including dimmers), control over the sound (music and television), and control over the natural light.

Privacy

There are two subtopics in the field of privacy, namely, waiting rooms and single-bed rooms.

This section describes the relationship of single-bed rooms to the privacy of the patient and the relationship between the waiting room and a lack of privacy. According to Mlinek and Pierce (1997), overhearing conversations at the reception desk was the main problem in the waiting room. Mlinek and Pierce (1997) suggested achieving a more audibly secure area by changing the structural design. Thus, the addition of background music or the use of physical barriers could be used to limit noise transmission and overhearing of conversations.

Firestone *et al.* (1980) examined the lack of privacy among residents of four-bed rooms in comparison with single-bed room residents. The study indicated that ward residents view their dwelling as less secure and feel less able to control social encounters occurring therein than do residents of single-bed rooms. Hutton (2002) examined the strong need for privacy with respect to the bathroom (using the toilet, showering, and grooming) for adolescents in hospitals. The study showed that a quiet space or room was important to the adolescents for activities such as reading and homework. However, a separate area was not seen as necessary for quiet activities that can be performed in the bedroom.

Summary of design features related to privacy to address with a level of evidence of two or higher:

Single-patient rooms, design of waiting rooms. For instance, solid walls instead of curtain walls.

Comfort

Comfort is divided into several subtopics, consisting of materials, art, view, visual comfort, acoustic comfort, and orientation. These topics describe the influence of the physical environment on the well-being of the patient. For example, comfort in the patient room is related to having a single-bed room instead of staying in a multi-bed room (Ulrich *et al.*, 2004). Comfort is not related to the definition of the state of mind expressing satisfaction with certain physical environmental parameters, such as thermal comfort, per se.

Materials

The use of carpet is frequently associated with the home environment but rarely with the hospital environment. There are studies that support the idea of using carpet, whereas others categorically reject it. Cheek *et al.* (1971) identified a negative reaction from staff members towards the installation of carpet. However, the administration of the hospital considered it a success. For instance, the safety had been improved as well as the appearance of the unit. Secondly, carpeting was a success because it was incorporated into the design before people moved in, and an effort was made to have cleaning systems in place from the beginning. This type of success depends on situational and social organisational variables. However, the evidence is more empirically based than scientifically proven. In addition, the satisfaction levels of the respondents are difficult to measure. Another published study investigated a possible relationship between the contamination of patient room carpeting and the prevalence of *pseudomembranous enterocolitis* (PME). The usual cause of PME is toxicogenic strains of *Clostridium difficile.* Skoutelis *et al.* (1994) found no evidence that environmental contamination resulted in an increased frequency of PME in patients housed in carpeting rooms. However, carpeting should be considered as a potential reservoir of this organism.

Art

Ulrich and Giplin (2003) discussed how certain types of "psychologically appropriate" artwork, including representational images with themes relating to waterscapes, natural landscapes, flowers and gardens, as well as figurative art showing emotionally positive gestures and facial expressions, can reduce stress and improve outcomes such as pain relief. However, abstract or ambiguous images or emotionally challenging subject matter

can evoke dislike or other distinctly negative reactions among patients. According to Ulrich and Giplin (2003), the limited research on art supported the conclusion that art selection for HCF should be evidence-based.

View

Regarding the effects of the view from the window of the patient room, Ulrich (1984) demonstrated that patients with a view of nature (trees) had shorter postoperative stays, took fewer potent pain drugs, and received more favourable comments about their condition in nurses' notes than did matched patients in similar rooms with a window facing a brick building wall. Following this strain of thought, Verderber (1986) noted that the most preferred window views among patients and staff were those of plants, the surrounding neighbourhood, and people and those that provided information about outside activities. In contrast, window views of architectural features (i.e., concrete buildings) or monotonous views were not preferred. If artificial substitutes for window views were necessary because of the lack of windows, patients and staff preferred representations of nature. Respondents were not satisfied with the following features: views into the hospital; the degree of personnel control of windows, screens, and curtains; and poor views from treatment rooms or the lack of windows. Moreover, in a study conducted on an intensive therapy unit (ITU), Keep *et al.* (1980) confirmed previous studies showing that most ITU patients are conscious of their surroundings and retain some long-term memory of their stay. Patients who received care in a windowless ITU, in contrast to those in an ITU with windows, had a less accurate memory of the length of their stay and were less well orientated regarding time during their stay. The incidence of hallucinations and delusions reported by patients was more than twice as high in the windowless unit.

Another trend found in research addressing views is distraction therapy. In this case, the term "view" does not necessarily mean a view from a window but a visual stimulation that will serve as a diversion in an effort to make painful procedures more bearable (Miller *et al.,* 1922). Following this line of thought, Diette *et al.* (2003) explored how the odds of better pain control were greater in the nature-distracted intervention patients than in the control patients, after adjustment for age, gender, race, education, health status, and dosage of narcotic medication. There was no difference in patient-reported anxiety and satisfaction. Other distraction techniques include virtual reality intervention for women receiving chemotherapy (Schneider *et al.,* 2004) and sensory stimulation (*snoezelen*) for the management of chronic pain (Shofield and Davis, 2000). In all of these studies, the group exposed to one of these distraction techniques reported significantly reduced pain and, in some cases, improvements in terms of disability (physical, psychological, and recreational), sleep, coping, and sickness impact profile. Other studies, such as that by

Ulrich *et al.* (2003), measured the blood pressure and pulse rates of blood donors to determine that donor stress was lower during periods of watching no television (blank monitor) than of watching daytime television. Additionally, during conditions of low stimulation (nature tape + without TV) and high stimulation (urban tape + TV), pulse rates were much lower with the nature tapes. A similar study by Ulrich *et al.* (1991) demonstrated faster recovery from stress when participants were exposed to a tape of a natural setting than those exposed to tape of an urban setting.

Visual comfort

Visual comfort encompasses daylight factors, luminance, and luminance intensity and their effects on people. Access to daylight in HCF seems to have a significant impact on patients as well as on staff. Eastman *et al.* (1998) used bright light treatment for winter depression. The study showed that bright light therapy had a specific antidepressant effect beyond its placebo effect, but it took at least three weeks for a significant effect to develop. Similarly, Lewy *et al.* (1998) compared both morning and evening light treatments of patients who were experiencing winter depression and established that morning light was at least twice as effective as evening light in the treatment of seasonal affective disorder. Regarding this field of study, Beauchemin and Hays (1996; 1998) found that patients had shorter hospital stays when staying in sunny rooms compared with dimly lit rooms. Patients treated in sunny rooms had an average stay of 16.6 days compared with 19.5 days for those in dim rooms. Moreover, there was significant difference between women and men. Mortality in both sexes was consistently higher in dim rooms. Choi *et al*. (2012) showed that there appears to be a significant relationship between indoor daylight environments and a patient's average length of stay. They also noted that the high illuminance in the morning seemed to be more beneficial than the light in the afternoon.

Moreover, materials with qualities such as glare were related to the healing environment. For example, polished floors are a common source of glare and pose problems for people with visual impairments. Therefore, the use of matte surfaces is not only convenient but also solves the problem of glare (Burton and Torrington, 2007; Weismann *et al.,* 1991).

Acoustic comfort

Blomkvist *et al.* (2005) indicated that the improved acoustics had affected the psychosocial environment. The study showed that improved acoustic conditions in the healthcare environment reduce risks of conflicts and errors. When considering noise and room acoustics, the most important parameters are sound pressure level and reverberation time. These parameters are crucial in creating supportive environments, both in terms of supporting hearing and of reducing negative effects associated with sounds and noise (van

Hoof *et al.,* 2010). The negative effects of noise are associated with a patient's recovery (Bayo *et al.,* 1995) and increased levels of stress (Toph, 2000). Regarding the background noise level, Allaouchiche et al. (2002) studied the noise in a post-anaesthesia care unit (PACU). They found that high noise levels were present in the PACU and that most of these noises could be prevented. However, noise was not perceived as the main cause of discomfort by patients. In a similar study, Bayo *et al*. (1995) indicated that the most important noise sources were located primarily inside the hospital. They found that noise levels present in the hospital mainly affected the patients' comfort and, to a lesser extent, the patients' recovery. One of the main repercussions of a high noise level is the effect on patients' quality and quantity of sleep (Hilton, 1976). Quality of sleep in a respiratory intensive care unit (ICU) was poor for all patients; no complete sleep cycles were experienced. Sources of disturbance were mainly therapeutic procedures, staff talking, and environmental noises. Most disturbances were linked to the presence of other patients in the multi-bed unit. Moreover, sound peaks greater than 80 dB(A) and erratic patient interruptions by staff left little time for condensed sleep (Meyer *et al*., 1994). In an attempt to implement solutions, Moore *et al*. (1998) reduced sound levels on patient care units by 6 dB(A) on average by closing patient doors, a change that patients readily perceived. Conversely, in the ICU, closing doors increased noise levels, presumably because most noise emanates from equipment within the room (Ogilivie, 1980). Harris and Reitz (Harris and Reitz, 1985) studied the effects of room reverberation and noise on speech discrimination by older adults. They demonstrated that older normal-hearing subjects performed much poorer than younger normal-hearing subjects under the reverberant noisier condition, and that there was a drastic 48% decline in speech discrimination among older adults with a hearing impairment from the best acoustic condition (quiet + shorter reverberation time (RT)) to poorest (noise + longer RT). For healthcare facility design, the findings imply that consideration should be given to providing sound-absorbent ceilings and other measures that shorten RT and reduce noise propagation, thereby increasing speech discrimination among older patients and possibly older staff.

Orientation

Holahan (1972) showed that seating patterns exerted a powerful control over the amount of social interaction among patients in a dayroom setting. Arrangements with chairs positioned shoulder-to-shoulder along the dayroom walls strongly suppressed social interaction. By contrast, arranging chairs around small tables in the middle of the room increased interaction, especially among socially inclined patients.

Location and site are aspects of the orientation subtopic. Evidence from various studies suggests that animals and pets, plants, views of natural landscapes, and active wilderness

experiences have positive effects on human health and well-being (Frumkin, 2001). Additionally, there is a clear preference among staff and patients to be surrounded by natural open settings (Barnhart et al. 1998). A significant portion of the literature on healing gardens, such as Leibowits (1979), Kromm and Kromm (1985), Tyson (1998), Cohen-Mansfield and Werner (1999) and Zeisel and Tyson (1999), focused on the effects of gardens on persons with dementia. However, the scope of this study is limited to hospitals and clinical settings that do not include special population clinics or nursing homes.

Secondly, there is increasing evidence that simply viewing gardens can mitigate pain. In addition to reducing stress and pain, gardens can heighten satisfaction and facilitate wayfinding or navigation in healthcare buildings for patients and visitors (Ulrich, 1991). Wayfinding is important because if PF or staff have difficulties orienting themselves within the HCF, they may become frustrated and disoriented, which in turn may lead to experience stress (Moeser, 1988).

Summary of design features related to orientation to address with a level of evidence of two or higher:

Single-bed rooms, materials without glare, windows with a view, daylight and wayfinding.

Family support

Visitors to the hospital may play an important role in patients' recovery, but there are also other serious implications, such as transmitting of infections and breeching respect for hospital norms. Hamrick and Reilly (1992) indicated that open visiting hours were not associated with increased infection rates. Pettinger and Nettleman (1991) argued that visitors spending more time in patient rooms was associated with improved compliance with norms. Compliance was higher for persons entering as a group compared with those entering alone. Astedt-Kurku *et al*. (1997) explored the role of visitors in the hospital. The authors argued that family members spent considerable time at their relative's bedside, most of them up to several hours a day. Approximately half of all visits (49%) took place in the patient room. Family members, who saw themselves as "close" to the patient, had the most positive effects on patients' mental status. Concerning the effect of family visits, there seems to be no consistent effect on patients' mental status because some patients improved after the visit whereas others experienced a decline in their mental status.

The significance of the waiting room is indicated, to some extent, in the study by Foss and Tenholder (1993) on the expectations and needs of persons with family members in an ICU as opposed to a general ward. The categories of family needs that were considered important or very important by respondents both in general wards and ICUs included the following: patient information, proximity and access to the patient (waiting room, overnight

accommodations), emotional support, and a physical environment to support personal needs (nearby bathroom, convenient telephone, comfortable furniture in waiting room, food available 24 hours a day).

Summary of design features related to family support to address with a level of evidence of two or higher:

There are no design features to address in the topic family support.

2.3.2 Staff outcomes

Staff outcomes were divided into the primary topics of organisation and functionality, technical support and comfort (Figure 3). These topics are addressed in this section.

Organisation and functionality

Relatively few studies have examined the workplaces of staff compared to those that address PF outcomes. One theme that has been receiving increasing attention over the last few years in the literature about healing environments is wayfinding. Moeser (1988) proved that mental representations of maps do not develop automatically in a complex spatial environment. The study showed that first-time visitors performed significantly better on objective measures of cognitive mapping than nurses with two years of experience working at the hospital. In addition to a complex floor plan, there are other elements that contribute to poor wayfinding and inadequate or conflicting cues such as colours and lighting (Brown *et al.,* 1997). In addition to these elements, clear and understandable wayfinding and maps are fundamental to becoming oriented in HCF. However, maps should be oriented so that the top signifies the direction of movement for ease of use (Ulrich *et al.,* 2004). Moreover, the number of signs available has a significant effect on wayfinding along many different measures including travel time, the frequencies of hesitations, the number of times directions were asked, and the reported level of stress. The results suggest that directional signs should be placed at or before every major intersection, at major destinations, and where a single environmental cue or a series of such cues (for instance, a change in flooring material) conveys the message that the individual is moving from one area into another. If there are no key decision points along a route, signs should be placed approximately every 4.6 to 7.6 m (Ulrich *et al.,* 2004).

Summary of design features related to organisation and *functionality to address with a level of evidence of two or higher:*

Directional signs should be placed at or before every major intersection.

Technical support

Most of the literature available on technical support is related to identifying problems that have a direct effect on staff and that could be addressed through design solutions or protocol interventions. For instance, Alexandre *et al*. (2001) evaluated a program to reduce back pain in nursing personnel, Caboor *et al.* (2000) introduced an adjustable bed height during standard nursing tasks to enhance the quality of spinal motion, and Dariaseh *et al*. (2003) examined musculoskeletal outcomes in multiple body regions and effects on nurses' work. The consequences of working conditions are thus known to some extent. However, the type of interventions to prevent these consequences appears to need exploration. In this sense, Garg and Owen (1992) investigated the efficacy of an ergonomic intervention in a nursing home. The study showed that with systematic and appropriate ergonomic intervention physical stresses can be significantly reduced, hence reducing the future risk of musculoskeletal injuries and, in particular, low-back injuries.

Regarding the furniture in the patient rooms of the hospital, there have been several investigations in the fields of ergonomics and nursing studies addressing transportation in hospital beds. Petzall and Petzall (2003) experimented with two types of wheels for transportation of patients in hospital beds. In their findings, standard small-diameter caster wheels made the bed easier to manoeuvre in limited spaces, whereas larger wheels on fixed axles made the bed more comfortable for long-distance transportation.

Summary of design features related to technical support to address with a level of evidence of two or higher:

Supporting systems, training in patient transferring, modifying toilets and shower rooms, and beds with different types of wheels for transportation.

Comfort

From the perspective of staff, noise levels were sufficiently high to interfere with their work and to affect patient comfort, and recovery. Other studies aimed to identify the most disruptive hours in a hospital and, in this respect, Gast and Baker (1989) confronted the hypotheses and previous studies that the "quiet hour" had higher noise levels than the "noisy hour". They concluded that possible explanations for this included visitors and open doors of patient rooms.

Summary of design features related to comfort to address with a level of evidence of two or higher:

There are no design features to address.

2.4. Discussion

This systematic review has identified a growing body of literature that examines the effect of the physical environment on the healing process and the well-being of PF and staff. The review encompassed mixed methods and qualitative studies. Although we identified several extensive studies, consisting of good examples of qualitative research, there was a general lack of consideration of the impact of outcomes in a holistic way. Most significantly, because the lack of strategies, methodologies and tools to measure include subjective concepts such as perception, privacy, comfort, and satisfaction of users in their interactions with the built environment, these features remain in the qualitative realm or have simple quantitative ratings. In addition, studies did not highlight the confounding parameters, for example in studying view and light.

This review has certain limitations. For example, the search strategy focused on specific keywords. Some relevant words outside of the field of the chosen keywords may have been excluded. For instance, keywords in the domain of building physics. Further, the search strategy was focused on numbered data sources. It has been noted that in the articles studied, no distinction has been made in HCF. Despite the endless epistemological and methodological debates, this type of research does not seem to meet the criteria of decision makers for the investment in new healthcare construction.

2.4.1 Reorganising topics and subtopics

The classification of users' perspectives in topics and subtopics is based on reviews by Ulrich *et al.* (2004; 2008). This raises the question of whether a reordering of the topics is actually needed. For example, one of the main concerns of patients is to avoid being subjected to human errors made by staff and medical professionals. However, nurses also consider the elimination of errors in their work as their main concern. Our suggestion is to add the topic "no errors" to the list of known staff needs. For example, the transmission of infection by bacteria on hands is reduced if hands are washed more often. An automated sink or faucet could also be among the solutions. However, as mentioned before, this is not considered a solution from the perspective of staff. Larson *et al.* (1991) found in their study that staff expressed negative attitudes about certain features of automated sinks. For instance, they avoided washing their hands when they were busy because of a 15-second water flow interruption programmed in the automated sinks.

Furthermore, indoor quality is mentioned as a subtopic related to safety and security. However, emphasising the importance of indoor quality of HCF actually indicates that this subtopic has become a new topic in its own right.

Another aspect is the frequency of subjects that fall into different topics. As mentioned in the preceding section, a single-bed room improves the privacy and comfort of the patient and is thus placed in both topic groups. Although privacy is an important performance indicator of the patient in a hospital, the trend of creating "residentiality" in new HCF has been spreading throughout the United States with positive reactions from patients (Martin *et al.,* 1990). Moreover, the effects of single-bed rooms have yet to be proven. These effects have become apparent primarily through research conducted on healing environments (the effects of light, sound, music, and art), whereas the concept itself has seldom been studied as a separate research project (Van de Glind *et al.,* 2007). Another example is that the literature related to the healing environment and the waiting room is based on the distribution of music and furniture. Routhieaux and Tansik (1997) claimed that the presence of music significantly reduced stress levels compared with the absence of music in the waiting room.

This finding illustrates the complexity of the distinction between the different topics in relation to the healing environment. Thus, these topics require clear descriptions.

2.4.2 Key findings

A few of the reviews, randomised controlled trials and experiments found in this review concern the topics of comfort (Table 1). These studies link specific design features or interventions directly to impacts on healthcare outcomes. Most of the evidence is found in the topic comfort and, especially, in the subtopics of view and acoustic comfort. However, there is a scarcity of evidence found in the comfort topic with the staff.

Hence, there is a need for more evidence-based research focussing on the following topics: the elimination of errors, safety and security, control enhancement, organisation and functionality, and staff comfort. Furthermore, the research should pay attention to procedures and the description of data collection and analysis. Rather than describing data, research is needed that explores in-depth perceptions, meanings, and the impact of these topics (as mentioned above) on PF and especially on staff in HCF.

The diversity of methodologies and perspective views used in these studies makes it difficult to synthesise all of the data. This review, however, draws attention to some key findings that may be useful for future research.

Key findings from this study include evidence that the physical environment has an effect on the healing process and the well-being of PF and staff. Furthermore, there is evidence that the built environment can contribute to reducing errors, falls, and infections; improving privacy and comfort; and enhancing control. However, several aspects remain to be discussed. For example, more attention should be given to the incidence rate and delayed

post-burn day of colonisation of the common infection versus the invasive burn-wound infection in the single-bed room. Regarding pneumonia and invasive burn-wound infections, the single-room unit had a lower frequency and later time of post-burn colonisation (McManus *et al.,* 1992).

The research also identified some design features related to the physical environment and the well-being of PF and staff. These features include single-patient rooms, identical rooms, technical equipment and indoor (environmental) quality. In this case as well, the literature is written from the perspective of the patients and not from the perspective of the care professionals. Moreover, articles that described staff outcomes are often related to the characteristics of working conditions. Features such as wayfinding or technical support are practical elements that improve the labour conditions of staff. However, there is lack of evidence on factors such as accessibility and those relating to the physical environment and the well-being of professionals. Further research is needed to determine what staff require in and from their work environment.

2.4.3 Integrated building design

For the design and construction of new HCF, it is important to understand the needs of stakeholders. Each of the stakeholders involved in such an operation has a unique set of beliefs and associated meanings about the surrounding environment (Tanja-Dijkstra and Pieterse, 2011), thereby adding to the complexity of a design process of HCF that considers many stakeholders who are involved in building a new healthcare environment (van Hoof *et al.,* 2010).

Another major difficulty is to ensure that practitioners clearly understand the research results reported in academic journals (Devlin and Arneill, 2003) and the subsequent implications of such results for the construction of new healthcare settings. The application of research findings, in practice, may be performed based on a clear theoretical framework that will help to position and relate the implications of certain studies. However, the problem is that there is a lack of consensus concerning the theoretical framework, given the current literature on healing environments (Daykin and Byrne, 2006). Some of the frameworks that were proposed are the following:

- Setting-related studies (such as single- versus multi-occupancy rooms (Chaudhury *et al.,* 2006);
- Systems performance-related studies (such as ventilation systems (Chow and Yang, 2003) and air conditioning (Charles, 2003; Hwang *et al.,* 2007);
- Illness-related studies (Zeisel *et al.,* 2003), including substance abuse and stress

(Grosenick and Hatmaker, 2000; Evans, 1984);

- Problem-solving studies (such as increasing the safety of patients (Clarkson *et al.,* 2004) and improving wayfinding (Bayskaya *et al.,* 2004); and

- Built environment features and characteristics (such as light (La Garce, 2004; Alessi *et al.,* 2005; Joseph, 2006), noise (Bayo *et al.,* 1995; Wallenius, 2004; Evans *et al.,* 1995), colour (Jacobs and Suess, 1975), temperature (Lu and Zhu, 2006).

The five frameworks mentioned above do not address the built environment in its entirety because they have been determined by researchers with backgrounds in the study of various aspects of HCF (Codinhoto *et al.,* 2009). According to Durmisevic and Ciftcioglu (2010), no current methodology was adequate to handle the different environmental features in a holistic way. Another factor is a lack of knowledge about the cumulative effects of various environmental aspects on health. In this regard, an adequate tool has yet to be developed for the efficient knowledge management and modelling of EBD data based on individual studies. As a result, Durmisevic and Ciftcioglu (2010) presented a framework concerning the design for a performance-based tool. This tool provided support for decisions during the design and evaluation of a healthcare setting by the overall design performance of various aspects.

2.5 Conclusion

Addressing the effects of the physical environment on the healing process and well-being of PF and staff has become increasingly important in HCF design and construction. We have investigated the meaning of physical environmental factors on PF and staff outcomes. It was found that evidence for staff outcomes is scarce. Most staff outcomes are empirically based and not scientifically proven. It has been noted that the literature presents a variety of theoretical frameworks and technologies in the study of health outcomes on patients that are unsuitable for future research on healing environments. This shortcoming is because most of these studies have focused on the perspective of patient needs or on the perspective of the designer. Another reason why the conclusions of the current study are interesting for healthcare organisations is that HCF are developing a more customer-oriented management approach. This means that for designing and constructing new healthcare settings or renewing HCF, it is also crucial to understand the needs and relationships between the staff and other stakeholders related to the built environment. The main challenges for further research are the specifications of staff needs and the integration of all these needs into the built environment of HCF.

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Chapter 3

A structural approach for the redesign of a nursing home

This chapter is based on the following paper published in Intelligent Buildings International

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Abstract

Long-term care facilities in the Netherlands try to implement new design approaches to enrich their environments and to cope with the changes and innovations in the Dutch healthcare sector. An enriched environment supports both quality of life of people with frail health and the well-being of the healthcare professionals who take care of them. Despite the increased attention devoted to built environments in relation to health, a gap in knowledge remains how to implement new design approaches. The aim of this study is to present a structural approach for a decision making process to help to create enriched small-scale care facilities for older people with a frail health condition. A case study was conducted to understand how the structural approach contributes to implementing design features of an enriched environment. The structural approach identifies the key factors (such as shared language, collective understanding, and involvement of stakeholders) that should be considered when developing such facilities and describes the critical steps for decision makers for such environment.. This case study provides a rich source of information from actual experiences for a better understanding of steering mechanisms for decision making by the management of small-scale care facilities.

Keywords:

Built environment; Participatory design; Age friendly environments; Care professionals

3.1 Introduction

In the Netherlands, 57% of the 811 healthcare facilities provide long-term care. Since 2009, the management of these facilities has been entirely accountable for the design of their buildings and the management of their real estate (van der Zwart *et al.,* 2010). In addition, technological innovations (like home automation), sustainability and the design of a healing environment have become increasingly important for Dutch healthcare building design (Appel-Meulenbroek *et al.,* 2010). New design approaches have been implemented in some long-term care facilities to ameliorate their environments and to cope with these innovations and trends. These organizations want to present themselves as being focused on care with a physical environment that supports the quality of life of older people and the well-being of the healthcare professionals who take care of them (Davis *et al.,* 2009; Dellinger, 2010).

This growing attention for building design as a means to shape healthcare environments that promote healing is based on the healing environments concept and evidence-based design (Zimring and Bosch, 2008). The Center for Health Design (2016) defined evidence-based design as "the process of basing decisions about the built environment on credible research to achieve the best possible outcomes". So far, this concept has been applied mainly with regard to hospital settings, wherein the effects of the physical environment on patient healing and staff well-being were also studied (Codinhoto *et al.,* 2009; Huisman *et al.,* 2012; Ulrich *et al.,* 2008). Many of the basic elements of healing or enriched hospital environments have thus been clearly identified (see for example Huisman *et al.,* 2012; Salonen *et al.,* 2013; Ulrich *et al.,* 2008), such as building physics aspects, layout and interior. Besides health, other proven benefits of enriched environments are enhancement of client satisfaction, promotion of healing and well-being, improvement in employees' satisfaction and strengthening of competitive advantage (Oi-Zhen *et al.,* 2015).

In this study, a long-term care facility, which is very different from a hospital setting, is examined. Designing long-term care facilities is a complex and dynamic process, especially when it involves stakeholder groups with complex demands, such as older people with psychogeriatric disorders (Van Hoof *et al.,* 2015). In addition, the organization and design team have to translate the evidence-based design findings from hospital studies into design solutions that are beneficial for this specific healthcare environment as there is scant research on long-term care environments. They must also realize that there will not be a 'healing' effect and therefore the aim is to try to design an environment that may enrich the lives of older people who have frail health conditions and which supports them in their

daily activities and helps them led a meaningful life.. Quality of life refers to the total living experience (Singh, 2014) for which the living environment is only one of the contributing factor.. . An enriched environment refers to technology and architectural solutions that support the well-being and quality of life of the residents and optimize the work process of healthcare professionals (Huisman *et al.,* 2012; van Hoof *et al.,* 2014, 1-12; Elf *et al.,* 2015).

However, before designing any building, it is vital to understand the values of the various stakeholders involved in the design process. Specifying the needs of stakeholders in integrated building design is a challenge for designers. Each stakeholder has a unique set of beliefs and requirements that are associated with the built environment (Tanja-Dijkstra and Pieterse, 2011). Despite the increased attention devoted to built environments in relation to health, there is still a gap in knowledge as to how to integrate the values of diverse stakeholders into actual building design. A few studies have developed theoretical frameworks that are useful in categorizing various indoor environmental factors and relating them to health outcomes (e.g. Codinhoto *et al.,* 2009). However, Durmisevic and Ciftcioglu (2010) concluded that none of the currently available methodologies can successfully integrate both indoor environmental factors and health outcomes.

This study aims to present a framework for a structural approach for a decision making process to help to create enriched small-scale care facilities for older people with a frail health condition. Small-scale care in the Netherlands is aimed at providing nursing care in small groups (6 – 10 residents per group) while emphasizing normalization of daily life and encouraging residents to participate in activities (Verbeek *et al.,* 2010). The focus of this study was placed on redesigning a common living room of a small-scale care facility by using the perspectives of the different stakeholders via a participatory design approach. Participatory design is an approach that actively involves all stakeholders in the design process to ensure that the end results are practical and meet each stakeholder's needs (Kang *et al.,* 2015). Concepts are developed together with users so that they fit better with what users do and want to do. The aim of this study was to adapt, develop and evaluate a structural approach when planning and (re)designing long-term care facilities. The structural approach presented in this study focused on understanding both the residents' and healthcare professionals' perception. It provides support for communication and collaboration for the difficulties that may arise in the design process.

In the next section we shall introduce the structural approach. First, the three steps for how to address the decisions of the design of an enriched environment will be described. Next, the steps will be applied in a case to illustrate and evaluate the approach in practice.

3.2 Methods

3.2.1 Towards a structural approach

The structural approach presented in this study consists of three steps: (a) exploration; (b) concretizing; and (c) evaluation (see Figure 3.1). These three basic steps are present in almost all participatory design research approaches and can be iterated several times (Spinuzzi, 2005). But whereas, in general, participatory design approach is applied in the early stages of concept design (e.g. Kang *et al.,* 2015), the structural approach introduced here will cover the entire building cycle. Another difference involves the setting. Participatory design often takes place in a laboratory environment (e.g Schuler and Namioka, 1993) whereas the structural approach is implemented in a real environment. The three steps of the structural approach are described below in more detail, which leads to a more elaborate version of the framework for the structural approach as shown in figure 3.2.

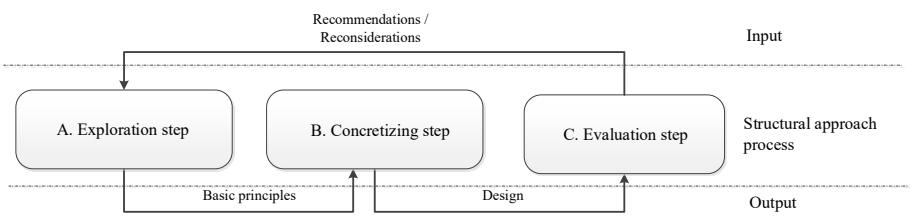


Figure 3.1. Steps in the structural approach.

Exploration step

The exploration step describes the activities that take place to answer and to inspire the exploration of open-ended questions such as, “What is an enriched environment?” or “How can we improve the quality of life of older people who have a frail health condition?” (Sanders and Stappers, 2008).

The aim of this step is to determine the basic principles (called output in Figure 3.1) for an enriched care facility for a particular organization. The exploration helps to obtain and define the needs and ideas regarding enriched care facilities of the participants who are representatives of the various stakeholders. All of the data are compiled in order to define the basic principles as an output factor and function as an input factor for the next step in the structural approach.

The exploration step includes measurements of the indoor environment (IE) and

observations of residents in the facility (figure 3.2). The following IE parameters should be included: light conditions, acoustics conditions, accessibility, safety, colour and contrast, interior, and the layout of the common living room (Huisman *et al.,* 2012; Salonen *et al.,* 2013; Ulrich *et al.,* 2008). Observations of residents should be focused on the interactions between residents, staff and the indoor environment as done by Aarts *et al.* (2014). They should take place in the natural surroundings of the participants and the researcher should not participate in any of the activities and the group (he or she should be a 'complete observer'). Additionally, semi-structured interviews with stakeholders provide further insights into users' needs in relation to the indoor environment. Visits to other project sites gave participants (facility manager, staff, and researchers) the same frame of reference.

All of this is followed by a workshop, which is designed to collect stakeholders' wishes and preferences with regard to the indoor environmental factors of the small-scale care facility and is meant to discuss any other relevant contextual factors. The result of such a workshop is a list of basic principles for the facility. The workshop can be guided by a facilitator (a researcher of the team) to stimulate creativity and to obtain a maximum of variety in input for the list of basic principles.

Concretizing step

The purpose of the concretizing step is to translate the basic principles for an enriched care facility collected in step 1 into values and functions. Furthermore, these values and functions are translated into a design. It is an iterative process in which the researchers and the stakeholders interact frequently, and are involved in discussion meetings (Spinuzzi, 2005). Such an iterative process contributes to the co-creation of a design with all participants. The aim of the categorization of the values and functions is to determine and address all relevant design features and Indoor Environment (IE) principles for the small-scale care facility. The discussion meetings increase the feasibility of design concepts that are chosen, because they help select the improvements for the environment based on the ambitions of the small-care facility and the basic principles of the various stakeholders (Vink *et al.,* 2008).

The concretizing step starts with categorizing the unstructured data on needs and preferences that are collected during the exploration step. Categorization should be conducted using the four eyes principle (Hiebl, 2015). This principle means that the categorization may not be made by individual actors alone but must be made by at least two actors. Based on the outcomes of the categorization process and possible expert meetings, one or more building design proposals can be developed. The design proposals visualize basic principles for the indoor environmental factors and design features of the facility

based on the needs and input of the various stakeholders. In addition, meetings with stakeholders are useful for reflecting on the design proposals and for eliciting comments and feedback. The outcome of this step is that the design integrates the basic and functional values of the residents, their family members and the staff.

Evaluation step

The evaluation step follows the completion of the design. The aim of the evaluation step is to define recommendations and reconsiderations (called input in Figure 3.1) for a possible redesign and to measure the subjective and objective effects, to adjust improvements and to evaluate the process (Vink *et al.,* 2008). It is important to gather information in order to assess whether the redesign meets all the requirements of the stakeholders.

The evaluation step includes a series of activities, such as a second round of IE measurements, interviews with representatives of healthcare professionals, and observations. The IE measurements are useful in determining whether the new setting meets IE requirements. The interviews and observations provide additional information about stakeholders' perceptions of IE in the new setting.

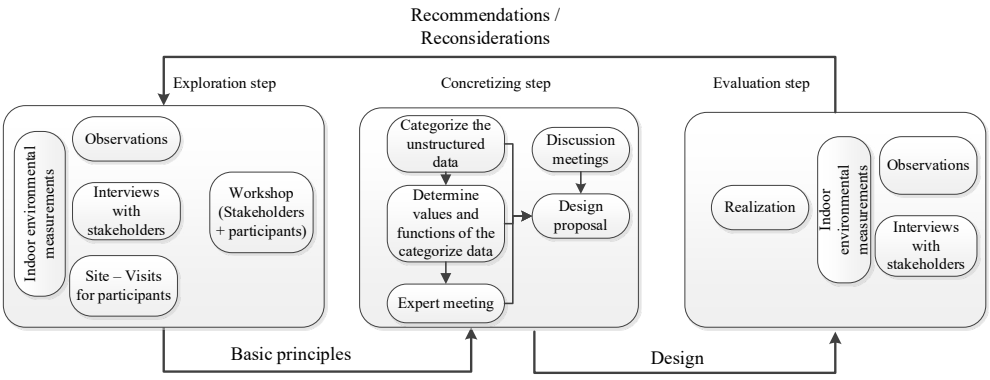


Figure 3.2. Framework of the structural approach; presenting the activities within each step.

3.2.2 Case description

The structural approach that was developed is applied to a small-scale care facility in the Western part of the Netherlands with the aim of creating an enriched care facility. In keeping with this goal, the board of the facility planned to renovate the common living rooms at one location. At this particular location, one common living room located in a low-rise building was selected for redesign. The other living rooms had the same layout, but were mirrored. Figure 3.3 shows the two common living rooms in a mirrored situation. Each common living room is used by six residents during the day under the supervision of four healthcare professionals. The residents spend the nights in their own bedrooms. The common living room to the left was used in this case study to apply the structural approach.

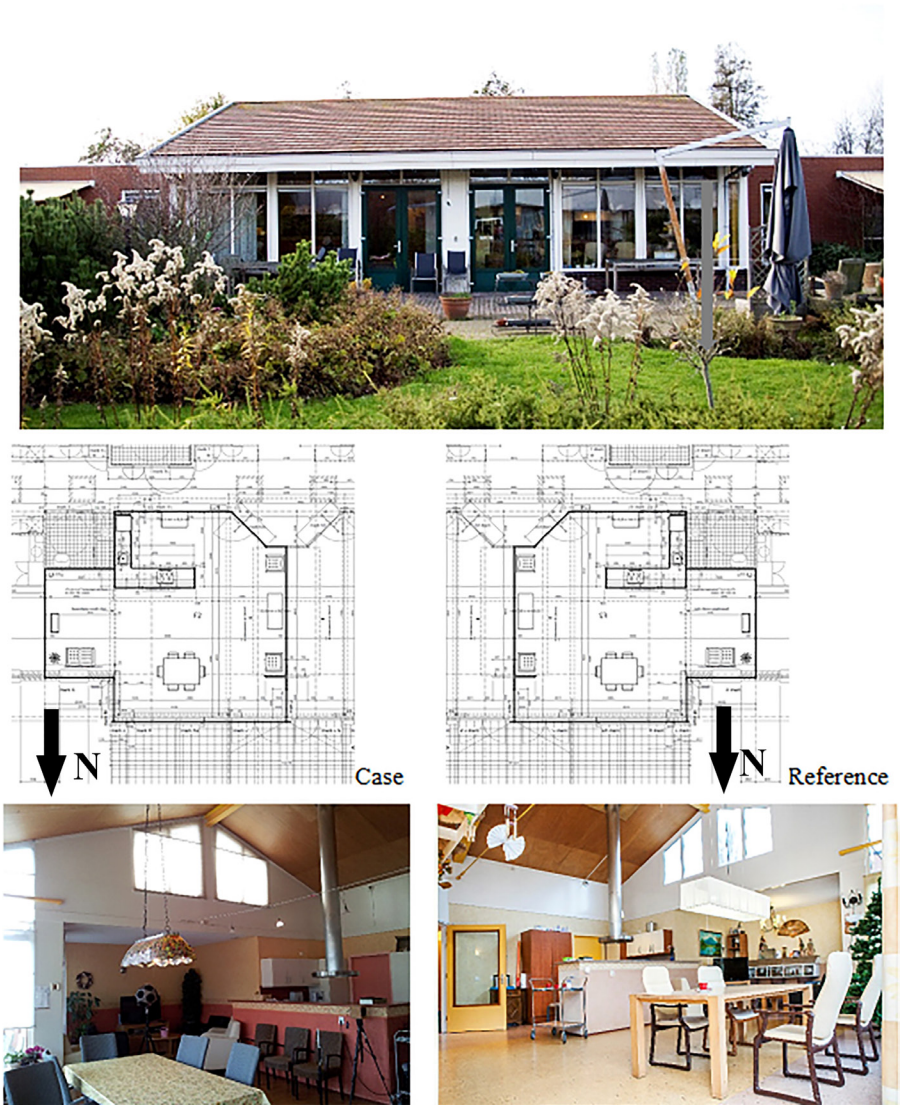


Figure 3.3. Case study situation of the two common mirrored living rooms.

The participants in this study were divided into four groups: (i) residents and members of the client council (n=27); (ii) healthcare professionals (n=19; 17 female and 2 males; age range 22 to 61), (iii) board and (facility) staff members (n=8), and (iv) researchers and experts (n=7). The first group participated in the exploration and evaluation step. The other three groups participated in all steps of the structural approach.

All residents that participated in this study suffer from psycho-geriatric disorders. The selection of residents was based on informed consent and the willingness of the residents and/or their legal representatives to participate in this study. The healthcare professionals were invited by their team leaders to participate in this study. The participants of group three and four were selected by having regard to their function, expertise and their willingness to participate in this study.

Procedure

The period of the exploration step took one year from September 2012 until October 2013. IE features included light and acoustic measurements. The point light measurements included the horizontal and vertical illuminance at relevant positions for the residents and viewing directions. This was done in two situations: once with the electrical lighting switched off and once with the electrical lighting switched on, in combination with daylight. Illuminance was measured with a Konica Minolta Chroma meter (type CL-200). The light measurements took place during the summer period and winter period. The room acoustics were described according to the following parameters: reverberation time, back ground noise and speech intelligibility. The acoustic measurements were done according ISO 3382-2/3 and IEC 60268-16 and were measured with a sound level meter RION (type NL-32 and serial number 0111084). The observations were conducted during the day from 09:00h up to and including 17:00h. The position of the observer was in consultation with the healthcare professionals on site.

The period of the concretizing step took eight months from October 2013 until June 2014. The data were structured and ordered over the course of four discussion meetings over a period of three months, where researchers and practitioners discussed the data with the goal to achieve alignment and to validate the content. The unstructured data were also discussed with an expert from the King's Fund of the United Kingdom. This group has a specific program to help develop supportive designs for people with dementia (The King's Fund, 2013). The design proposals were developed over the course of four discussion meetings over a period of four months, where researchers and practitioners discussed the two proposals with the goal to choose one design.

The period of the evaluation step took eight months from June 2014 until January 2015. The design of the common living room was realized over a period of four months. The second round of measurements, the interviews and observations took place two months after the realization of the design.

3.3 Results: Application of the structural approach

The following sections describe the structural approach in practice. The output factors, the basic principles and the design, as well as the input factors and the recommendations/ reconsiderations for a new structural design process are described.

3.3.1 Exploration: Basic principles

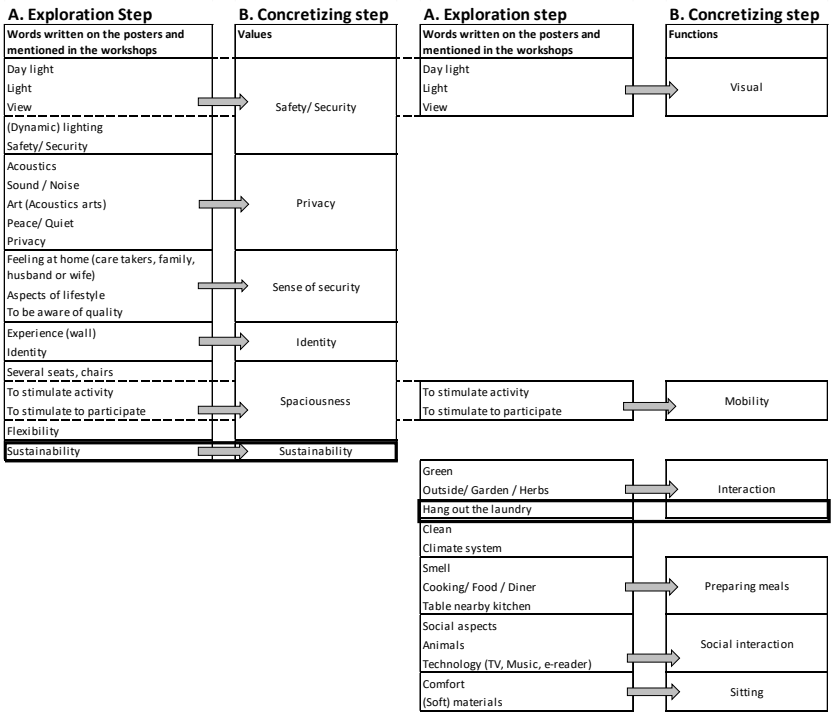
The site visit to a reference project (a new building of the long-term care facility) identified the following key factors: (a) identity; (b) feeling at home; and (c) satisfaction. The indoor environmental measurements (see chapter 4, sections 4.1.3.2; 4.2.3.2; 4.3.2.5) and the semi-structured interviews with healthcare professionals (N=19) supported the observation that the room's layout, lighting (< 500 lux) and acoustics (> 50 dB(A)) did not comply with the current standards. The needs and ideas were summarized using the words written on the posters and mentioned in the workshop and are shown in Table 3.1.

3.3.2 Concretizing: Design

The translation of the values and function needs to be done in an accurate way with the mission and vision of the organization in mind, after which these were prioritize to the different basic principles in the proper order aligned with the ambitions of the organization and the various stakeholders.

Table 3.1 shows the translation of the unstructured data into the structured and ordered outcomes. For example, the terms experience, wall, aspects of lifestyle, feeling at home, and identity were combined in the value 'identity'. The value 'identity' led to the principle to create an environment in which the residents can identify themselves with. In addition, 'to stimulate activity' and 'to stimulate to participate' were combined in the function 'mobility'. The function 'mobility' led to the guideline to create an environment with an accessible design for residents and healthcare professionals.

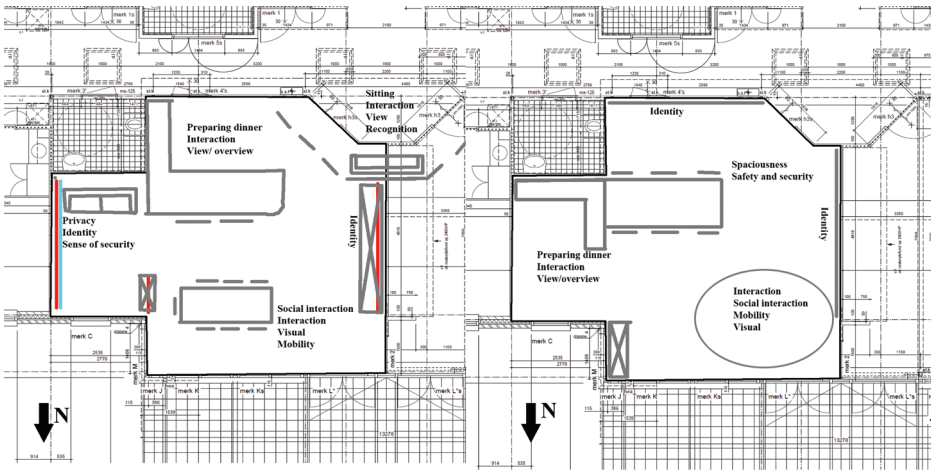
Table 3.1. The translation of the unstructured data into structured and ordered outcomes.



Based on the discussion meetings and expert meeting two new items were added to the structured and ordered data – sustainability and hanging out the laundry – which represented value and function (see the black box in Table 3.1). The values and functions, deduced from the concretizing step, were the basic principles and guidelines which led to the two design proposals.

The design proposals took the floor plan layout, colours, acoustics and lighting plan into account. Figure 3.4 shows the two design proposals for the common living room. The aim of the first proposal (left) was to create a safe home environment with a focus on the privacy of the residents and to stimulate interactions between residents and healthcare professionals. Special attention was devoted to creating an identity through an experience wall on the right and left side of the common living room. Furthermore, a private seating area was created where the residents have been offered the possibility to receive visits from their family. The aim of the second proposal (right) was to create spaciousness, stimulate interaction and align the floor plan of the room with the aforementioned values and functions. To create spaciousness and to stimulate interaction between the healthcare professionals and residents, the kitchen was replaced to the left side of the common living room. Furthermore, the replacing of the kitchen created a better overview of the common

living room and enhanced the safety and security of the residents.



Proposal 1: Safe home environment

Proposal 2: Spaciousness and interaction

Figure 3.4. Two design proposals.

The discussion meetings and interviews identified the key factors for examining the design proposals. These key factors were accessibility, technical feasibility, encouragement of mobility and social interaction, identity and safety. Based on these key factors, proposal 2 was thought to be more successful in creating more open space and in encouraging mobility and social interaction. Additionally, it provided strategic value with respect to creating an enriched environment. Figure 3.5 shows the floorplan of the design and the common living room in the new situation. The main factors of the design were replacing the kitchen to encourage interaction, implementing a lighting plan with equal distances to spread evenly over the space, improving the acoustics, color and contrast for visual functioning, creating sightlines to enhance safety and security, and creating a spacious floor plan to encourage mobility.

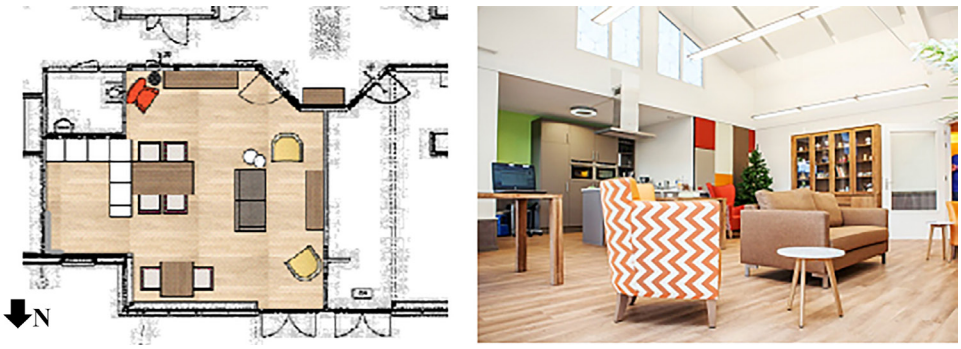


Figure 3.5. Common living room design and the new situation.

3.3.3 Evaluation: Recommendations and reconsiderations

The evaluative interviews corroborated the view that the new layout of the room stimulated interactions between the staff and the residents. In addition, the new setting increased the spaciousness of the room. The indoor environmental measurements supported the view that the light and acoustic conditions were improved and did indeed meet current standards. Observations also attested to the fact that residents from the reference living room were present daily in the redesigned living room instead of their own living room.

3.4 Discussion

The structural approach that was applied in this study contributes to design decision making processes by including the perspective of multiple user groups on how to add value with healthcare real estate. In the following sections, the implications for theory, as well as the implications for practices and future studies shall be discussed.

3.4.1. Implications for theory

The design outcomes in the long-term care setting of this study contribute to existing literature on the home environment. Research on the home environment showed that accessible and adaptable design can lead to reduction of emotional and physical demands and that it stimulates a sense of comfort and independence among residents (Olsen, *et al.,* 1996; Soilemezi *et al.,* 2017). Also, an open lay-out enhances the visibility and makes monitoring and interaction with the carers easier (Olsen *et al.,* 1996; Askham *et al.,* 2007; Soilemezi *et al.,* 2017). In this study, we found that besides the lay out of the floor plan also the indoor environmental factors, such as light and acoustics, play an important role in the entire design process of long-term care facilities. Especially for residents of long-term care facilities. This target group has different demands regarding the indoor environment due to biological ageing, and multiple diseases.

From the literature it may be deduced that the initial phase in the design process is the most important one due to the critical decisions made during this phase. Additionally, this is the phase where the stakeholders share and discuss their ideas and space requirements and prepare for design decisions (Elf *et al.*, 2015). The aim of this phase is to identify the healthcare environment demands from multiple users' perspective and relate this to the healthcare organization's strategic plan. The exploration step and the concretizing step in the structural approach help to concretize and specify the ideas and space requirements of the multiple user groups in this phase. The evaluation step in the structural approach is important to evaluate the design and to learn lessons for a future design process. So, the approach adds more depth to existing theory on design processes.

The involvement of multiple user groups as equal design partners through the participatory design approach offers a number of benefits. These include shared decision making through using various methods in the structural approach and it results in more ideas and solutions for the actual design process. This study shows the possibilities and challenges of participatory design approach when a more frail target group in a long-term care setting is included. The structural approach might in turn lead to optimizing the care environment,

which contributes to residents' quality of life and healthcare professionals' well-being.

3.4.2 Implications for practice

Based on this case in which the structural approach is applied, the following recommendations and reconsiderations were identified to further strengthen the approach:

- Determine the various stakeholders of the small-scale care facility and ensure that representatives of the strategic, tactical and operational divisions are present to address basic principles;

- Stay involved during the realization phase and interact with the various stakeholders. Stakeholder feedback should be shared with the external suppliers and the management of the facility to ensure a quick response from the facility manager, if necessary;

- Involve external suppliers of the organization in this early stage of the structural approach; this will help to ensure that the basic principles that are set comply with the organization's goals;

- Facility members can and should play a critical role in understanding the specific needs of various stakeholders regarding indoor environment factors to improve the management of the indoor environment.

3.4.3 Future studies

Further research is needed to optimize interventions in the indoor environment of small – scale care institutions and to understand how these interventions contribute to the quality of life of older people who have a frail health condition and the well-being of healthcare professionals. For example, the results obtained for the basic principles and design development process can be used as a starting point for further studies aiming to optimize the interventions and to determine the main factors of the indoor environment of small-scale care institutions from healthcare professionals' and residents' perspective.

Another relevant aspect for future research is to gain more insight into the decision making by those responsible throughout the entire design process. This study focused on the development of the structural approach and the outcomes of such an approach, which resulted in the redesign of a common living room in a long-term care facility.

But in general the design making by managers during design process, for example how they weigh different design solutions and make a choice that one is favourable over the other, remains a black box. Opening this black box with further research will be useful for more insight in decision making by facility managers, staff and boards of long-term care facilities.

3.5 Conclusion

This study provided an example of how decision makers can structurally address the creation of an enriched environment for older people who have a frail health condition. The structural approach that was developed gave valuable information to the healthcare organization about whether the basic principles actually met the user's needs.

The structural approach also helped to create a shared language and collective understanding of the design features of an enriched environment and contributed to a design that works for both groups, namely the residents and healthcare professionals. The strategic involvement of healthcare professionals in the initial phase and design process was essential for integrating knowledge of the care process into architectural design. In addition, the structural approach fostered a better understanding of the steering mechanisms for decision making by the facility members, staff and board members of small-scale care facilities.

Ethical considerations

In the Netherlands, this type of research is not covered for review by the Medical Research Involving Human Subjects Act (http://www.ccmo-online.nl).

The management of the organization agreed on the IE measurements, the observations of clients and interviews from the start of the project and were involved in the planning of the project. In the organization, it is standard policy to inform the client board about the research project. The client board approved of the research project.

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Chapter 4

A user-oriented focus on indoor environmental factors

Long-term care facilities have the ambition to distinguish themselves: a) in care provision; b) offering a sustainable environment; and c) as a good employer (Joseph *et al.,* 2016; Feinberg, 2012; Kort, 2012). They aim to represent an organisation that focuses on care and the physical environment of the residents to support well-being, activities of daily living, and quality of life of residents while optimising the work processes of healthcare professionals as well (Van Hoof *et al.,* 2014). However, to implement a strategy with the focus on well-being, board members, corporate real estate/facility managers and technical staff need a better understanding of how they can adapt the indoor environmental conditions and systems to enhance the activity and participation of older people and support the healthcare professionals during their work (Joseph *et al.,* 2016; Sinoo *et al.,* 2012).

This chapter describes three case studies that investigate how multiple user groups can be involved in the design decision-making process of long-term care facilities. Each subchapter identify healthcare professionals' and residents' perception of one indoor environmental factor in the care environment as input for the design decision-making process.

Subchapter 4.1: Redesign of lighting conditions in a nursing home

This subchapter is based on:

Huisman, E.R.C.M., Appel-Meulenbroek, H.A.J.A., Kort, H.S.M. "Redesign of lighting conditions in a nursing home: the perspective of different users", *submitted*

Abstract

Long-term care facilities, such as nursing homes, are not included in the majority of studies on healing environments. Furthermore, the studies were mostly written from the residents' perspective and rarely from the healthcare professionals' perspective or both. Therefore, the aim of this study is to clarify healthcare professionals' and residents' perception of light conditions in the care environment as input for making more optimal real estate decisions based on the best available evidence for lighting conditions in care facilities. This is done by involving the different user groups in the design and development process via different methods during a participatory design approach. First the lighting conditions in a Dutch long-term care facility were measured to gain insight into the added value of the lighting conditions for healthcare professionals' work perception and the well-being of the residents, followed by interviews with the professionals and observations of the residents. Next, a lighting design intervention was done in a common living room based on the residents' and healthcare professionals' experience, after which measurements, interviews and observations were repeated. The results of the intervention showed a significant improvement of the lighting conditions in illuminance and Correlated Colour Temperature values. Moreover, post-intervention interviews revealed that healthcare professionals appreciated working in the new situation. In addition, more residents were present in the common living room with the new light system. Insight in different user experiences creates the possibility to obtain better understanding of consequences of design decisions for the primary process of care giving.

Keywords:

decision making, facility management, healthy environment, participatory design approach.

4.1.1 Introduction

Lighting conditions are a highly important indoor environmental aspect for decision-making about organisational ambitions and potential real estate strategies. Light is an environmental factor related to daily functioning, symptoms and health conditions, according to the international model of Classification of Functioning, disability, and health (ICF) (WHO, 2002). Light is essential for vision and functioning in daily life and is used to supplement natural lighting that is available in the building (Webb, 2006). However, lighting can also have an impact on peoples' perception and responses to the environment and improve the quality and overall experience of building users (Aries *et al.,* 2010; Al horr *et al.,* 2016). Additionally, light can improve some cognitive and non-cognitive symptoms of psychogeriatric disorders (e.g., disturbed sleep-wake pattern; agitation) (Hanford and Figueiro, 2013). Although the added value of lighting and use of daylight within buildings is clear, simultaneous analysis of its experience by different user groups remains a research gap. This is especially a challenge for care facilities due to the different and somewhat conflicting needs of residents and healthcare professionals.

Designing long-term care facilities is a dynamic and complex process, especially when it involves different user groups with different demands, such as residents and healthcare professional (Joseph *et al.,* 2016; Van Hoof *et al.,* 2015; Nimlyat and Kandar, 2015). Understanding the characteristics of specific needs of various categories of building users could help improve the management of the indoor environment of long-term care facilities (Zeeman *et al.,* 2016; Huang *et al.,* 2013). However, the evidence regarding technical and architectural solutions in long-term care facilities is still limited. Long-term care facilities are not included in studies on healing environments. The majority of studies on healing environments are performed in hospital settings and not in long-term care facilities with frail older people (e.g., Kim *et al.,* 2015; Sharan *et al.,* 2014). Furthermore, the studies were mostly written from the residents' perspective and rarely from the healthcare professionals' perspective or both (Huisman *et al.,* 2012; Tanja-Dijkstra and Pieterse, 2010; Ulrich *et al.,* 2008).

Therefore, the aim of this study is to identify healthcare professionals' and residents' perception of light conditions in the care environment as input for making more optimal real estate decisions based on the best available evidence for lighting conditions in care facilities. This is done by involving the different user groups in the design and development process via different methods during a participatory design approach.

4.1.2 Background

The focus in this study is on the redesign of lighting conditions including the perception of multiple user groups. As the quality of the human eye decreases along the years, an adaptable light system is recommended in long-term care facilities. In that case, the environment would be able to 'adapt' along with the person with the possibility to increase the illuminance over time. For people above the age of 60 years the illuminance level should be multiplied three to eight times (Aries *et al.,* 2010). Several studies found that in general the amount of light in long-term care facilities is insufficient to meet such increased visual needs of the residents (Joseph *et al.,* 2016; Sinoo *et al.,* 2011; Van Someren, 2000). When residents live in an environment with too low illuminance levels, the risk of falling is undesirably high, but also the use of sleep medication is common and healthcare professionals need to spend valuable time on managing the restlessness of the residents (Hanford and Figueiro, 2013; Wong *et al.,* 2014). On the other hand, several studies (e.g., Forbes *et al.,* 2009) described the effect of light therapy applied to older people with dementia as treatment to reset the biological clock, improve cognitive functioning, and reduce behavioural symptoms (Figueiro *et al.,* 2008; Hanford and Figueiro, 2013; Aarts *et al.,* 2016).

For healthcare professionals, adequate and appropriate lighting is also important to perform their visual tasks efficiently and accurately. For example, sufficient lighting in the work environment where they perform daily tasks decreases errors during medication preparation and dispension (Joseph *et al.,* 2016; Kim *et al.,* 2015; Ulrich *et al.,* 2008; Salonen *et al.,* 2013; Buchanan *et al.,* 1991; Mahmood *et al.,* 2009). In addition, insufficient lighting conditions in the work environment can adversely affect their health and safety and job performance due to, for example, eye tiredness or dry eye symptoms (Vahedi and Dianat, 2014; Van Tilborg *et al.,* 2017). Optimal lighting conditions for offices have been studied extensively, resulting in a better understanding of the lighting conditions necessary for visual performance and to avoid discomfort (Boyce *et al.,* 2006), but such studies are scarce for care environments. To investigate the lighting conditions and to gain insight in employees perception on lighting conditions in a realistic care environment can provide more specific and additional information about the lighting conditions in the work environment of healthcare professionals (Van Duijnhoven *et al.,* 2017; Vahedi and Dianat, 2014).

Sufficient lighting is beneficial for both residents and healthcare professionals (Salonen *et al.,* 2013; Boyce and Wilkins, 2018). For a new design or retrofitting an existing environment in a long-term care facility, it is important to be aware of the impact of

different artificial lighting strategies on different user groups and take these into account (Joseph *et al.,* 2016; Salonen *et al.,* 2013). However, it is still challenging to understand the optimal lighting conditions in healthcare facilities due to different needs of the multiple user groups (Valerio *et al.,* 2016). Thus, identifying residents' and healthcare professionals' experiences is beneficial for developing a new design or retrofitting an existing environment.

4.1.3 Methods

4.1.3.1 Study setting

To identify residents' and healthcare professionals' experiences with regard to lighting conditions in their living and work environment, a field study was conducted at a Dutch long-term care facility in the western part of the Netherlands. Two locations of a long-term care organisation were examined to see how the light conditions could contribute to residents' and healthcare professionals' well-being (Figure 4.1.1). Location A was a four-floor building with three wings. Location B was a single floor building. In total, six common living rooms (four in location A and two in location B) were assessed for the field study. The common living rooms for the assessment were selected with the staff and based on the availability to access the room to execute light measurements. The layout of the long-term care facility was such that six bedrooms were connected to one common living room; the concept of small-scale living (Verbeek *et al.,* 2010). This concept means that during the daytime, residents use the common living room that is connected to their bedrooms. Each common living room had an open-plan kitchen, a large table, and a seating area with a television. During the day, two staff members, including nurses, were available per common living room. All residents that participated in this study suffered from psycho-geriatric disorders. The selection of the participants was based on informed consent and the willingness of the residents and/or their legal representatives.

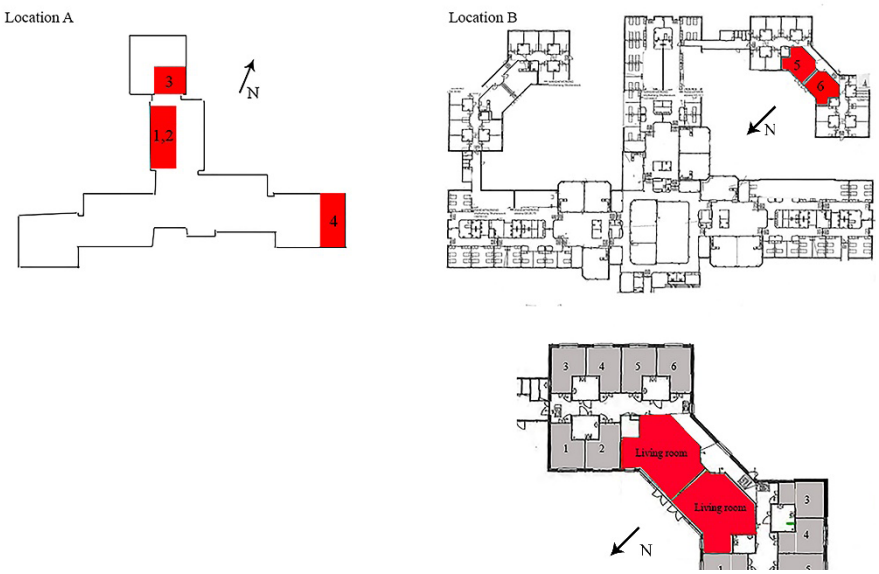

Figure 4.1.1: Situation and orientation of location A and B.[1]

1 Red: the positions of the common living rooms. Room 1 and 2 were located, respectively, on the second and third floor. Common living rooms 5 and 6 were located at location B.

4.1.3.2 Study design

In this field study, a combination of different methods was used to gain insight in the entire experience of the light conditions from the perspective of multiple user groups and the decision-making process towards an optimum light intervention (figure 2). These methods were based on a structural design approach to involve users in the design process (Huisman *et al.,* 2018; Abras *et al.,* 2004). Figure 4.1.2 shows the framework of the structural approach of the design, development, and evaluation process in this field study. The structural approach was divided in three different steps: the exploration step, the concretizing step , and the evaluation step. In these steps, the following activities were taken: light measurements to measure the current light conditions (1.1), interviews with healthcare professionals (1.2), observations of the residents to obtain insight in their light-related behaviour (1.3), selection, development and realisation of the intervention (2.1-2.3), and evaluation of a non-pharmaceutical intervention (3.1- 3.3). These activities were taken for a better understanding of a) the current perception of the light conditions in the long-term care facility; b) possible solutions to adapt the light conditions; and c) the decision-making process of the organisation. In the following sections, the three steps are described in more detail.

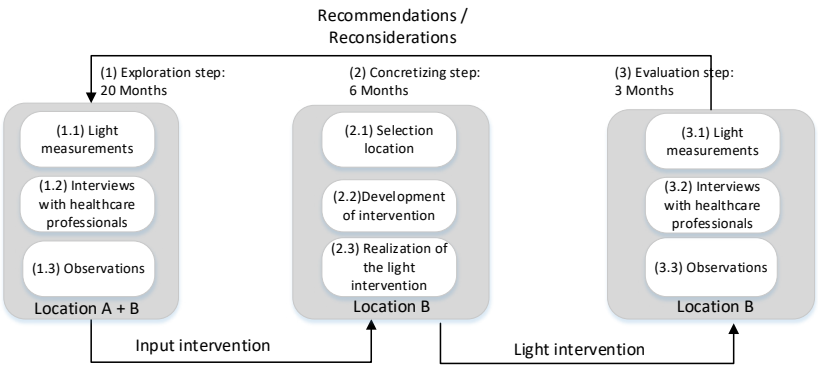

Figure 4.1.2: Framework of the structural approach; presenting the activities within each step in this field study based on the participatory design approach (Huisman *et al.,* 2018)

Step 1: Exploration

The first activity (Figure 4.1.2; activity 1.1) in the decision-making process for the light intervention was to collect information regarding the current lighting conditions in the common living rooms of location A and B. The measurements were performed between July 2012 and the end of December 2014 during daytime between 09:00 and 17:00 h. The first measurements were conducted on 12th July 2012 (Location A; T. 15 °C; Overcast). The common living rooms of location A were selected based on different orientation and floor level. The point measurements included the horizontal and vertical illuminance and the correlated colour temperature (CCT) of both the daylight as well as the electric lighting at different positions and for different orientations in the room (Figure 4.1.3). This was measured with a Konica Minolta Chroma metre (type CL_200). The horizontal values are measured at table level (0.75m). The vertical values are measured at the same point at eye level of a sitting resident, in the viewing direction of the resident (1.10m). The point measurements were conducted near the most frequently used sitting positions of the residents in the common living room. In addition to the measurements in all common living rooms, an inventory of the electrical lighting was taken by the first author.

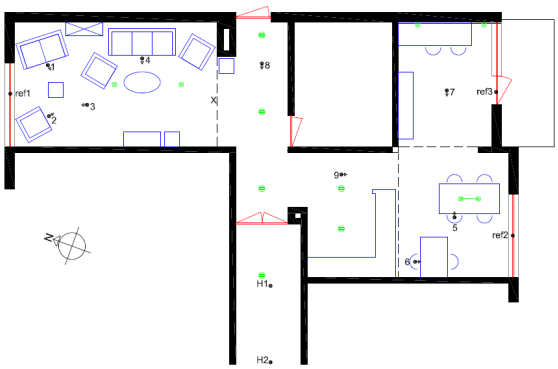

Figure 4.1.3: lay out of living room 4, with the electric lighting (green) and the measurements points.

The differences in measured illuminance levels and CCT values in the common living rooms between a daylight situation and a situation with daylight plus electrical lighting situation at location A were explored by Kruskal-Wallis *H*- test for two or more independent samples. The differences in measured illuminances and CCT between location A and B were explored by Mann-Withney *U*-test for two independent samples. The critical *p*-value was set at 0.05.

Further information regarding the light conditions of the common living rooms was

obtained through interviews with healthcare professionals (Figure 4.1.2; activity 1.2). The healthcare professionals were selected because they were one of the primary users of the common living room. Moreover, they could address issues regard light, the perception of their work environment, their health and residents' health. The semi-structured interviews were conducted to obtain insight in the perception of the healthcare professionals of their well-being and related aspects of the lighting conditions that facilitated or restricted their work activities. Twenty-two healthcare professionals were invited by the team leader of the location to participate in the interviews. They received a letter in which a clear description of the study was provided. In total nineteen healthcare professionals were willing to participate in the study (17 at location A and 2 at location B; 17 females and 2 males; age range of 22 - 61 years). The interviews occurred at the workplace of the respondents. In all phases of the interviews, the main questions were followed by subsidiary questions to invite the healthcare professionals to elaborate on their perception of the lighting conditions in their work environment. The interviews were guided by a predefined topic list, but there was room for deviation and variation for optimising the flow of the interview. The predefined topic list was generated on the basis of the literature and expertise of the research team, and the interview procedure was pilot tested with students. The research team included experts in work perception, building physics and Gerontechnology. The predefined topic list included questions about (i) lighting in general, (ii) lighting in relation to activities, and (iii) lighting in relation to incidents. All interviews were audio-recorded with the permission of the participants and were then transcribed and entered into MaxQDA version 12. First, each transcript was read in its entirety. Then, they were read a second time to develop codes. Defining the codes was done through two processes of open coding and axial coding. The open coding was done by marking the phrases in the transcripts that explained the perception and beliefs of the light conditions. An axial coding process was also done to rearrange the defined codes and to develop themes.

On site observations (Figure 4.1.2; activity 1.3) were conducted to collect information on the current light conditions in the common living room from the perspective of the residents. The observations included watching and recording the lighting related aspects of the residents. The predefined observation list was based on a comparable observation study by Aarts, et al. (2014) and included viewing direction and posture of the eyes, position in the living room, time spent in the living room and the activities of the resident . This observation list was filled out every half hour for every resident and for the environment from 09:00 – 17:00 h during eight days from Friday 30 November 2012 till Friday 11 January 2013. Two observations were conducted per living room and included one week day and one weekend day. The position of the observant was determined in consultation with the healthcare professionals, taking the usual positions of the residents into account.

Step 2: Concretizing: Selection, development and realisation of the intervention

The selection and development of the light intervention (Figure 4.1.2; activity 2.1-2.3) was based on the outcomes of the first three activities in the exploration step. Based on the findings in the first three activities and in consultation with the facility manager and the board of the healthcare organisation, location B was selected for an intervention. Reasons to select location B were that the illuminance levels were significantly lower when compare to location A. Furthermore, the healthcare professionals of location B mentioned that they used a summer and winter position of the furniture due to the lighting conditions in the common living room. Redesign of the common living room was based on the development of a lighting design plan as a non-pharmaceutical intervention. The goal of this intervention was to optimise the illuminance levels in the common living room and therefore positively influence the perception of the healthcare professionals and residents. A secondary goal was to strive to a homogenous setting with attention to task performance in the entire common living room. In the lighting design process, two different suppliers of lighting design were consulted to identify the requirements and possible lighting equipment. Each supplier made three proposals for the common living room and calculated the lighting parameters. Based on the goal of the intervention and the preferences of the organisation and in cooperation with the healthcare professionals and the facility manager, one supplier was chosen to make a final design for the lighting plan. For the intervention, the Waldmann amadea – 2 x 54 C Dali armature in the size 121 x 22.6 x 4.3 mm with a weight of 4.8 kg (CCT 4000 K, 4450 lm) was used instead of the former luminaire with incandescent lamps. In total, sixteen armatures were positioned at the ceiling of the living room. See Figure 4.1.3.

Step 3: Evaluation

After the intervention, an evaluation (Figure 4.1.2, step 3) was conducted to determine the effect of the intervention on illuminance levels and Correlated Colour Temperature (CCT) and healthcare professionals' experience. The light measurements were executed done again (Figure 4.1.3, activity 3.1) to measure post intervention illuminance levels and CCT values in the common living room in the new situation and in a reference common living room that was mirrored to the room where the intervention occurred and that room did not have any interventions.

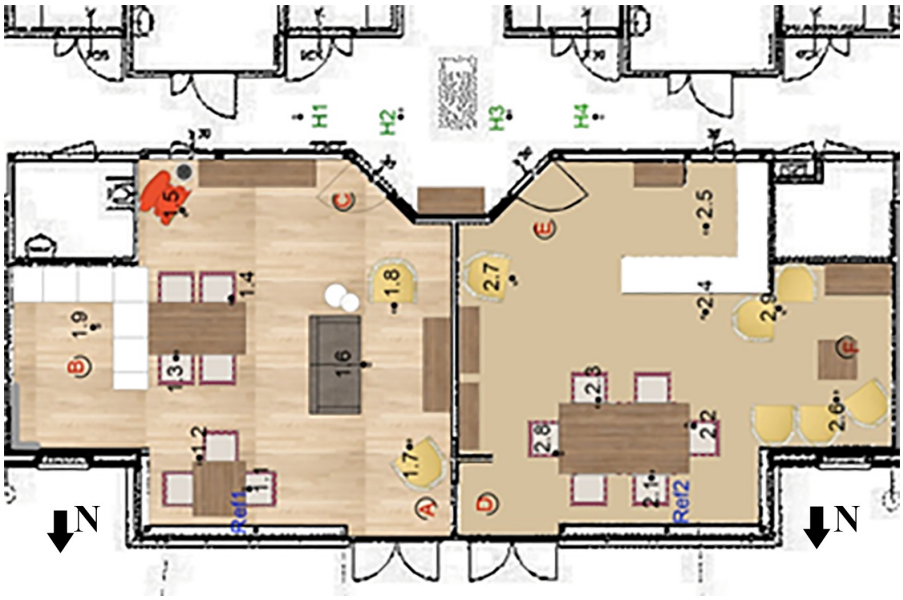

Figure 4.1.4: lay out of intervention room (left) and the reference room (right), with the measurements points.

The post-light measurements were performed on 6 December 2014 (T. 4 °C; partly cloudy) during daytime between 09:00 and 17:00 h. The differences in measured illuminances and CCT between the intervention common living room and the reference common living room were explored by Mann-Withney *U*-test for two independent samples. The critical *p*-value was set at 0.05. Additionally, interviews (Figure 4.1.2, activity 3.2) were held with three regular healthcare professionals working on the ward on which the intervention took place, to gain insight in the impact of the intervention on their professional well-being and performance. The study is executed in a field study to explore the framework of the participatory design approach, which makes it acceptable that the a small number of staff participated. Furthermore, six weeks after the intervention the observations (Figure 4.1.2, activity 3.3) were repeated to determine residents' light related behaviour. The observation study was performed during two weekdays and one weekend day and included the viewing direction and posture of the eyes. The differences in eye open or closed observations and eye direction between the intervention room and reference room were explored by Fisher's exact test. The p- value was set at 0.05.

4.1.3.3 Ethics

Board and management of the organisation agreed on the measurements from the start of the project and was involved in the planning of the project. Furthermore, in line with the policy of the organisation, the client board was informed prior the start of the project and they approved to execute the project. During data collection, the professional and family carers who were present, along with the residents, were informed about the measurements. Daily activities were not disturbed nor hindered by the measurement procedures.

4.1.4 Results

In the following sections, the results of the measurements, interviews and observations are described.

4.1.4.1 Exploration: light measurements; pre-conditions

The average value of illuminance (E_v and E_h) and correlated colour temperature (CCT) of the common living rooms at location A and B were determined (Table 4.1.1). A Kruskal-Wallis *H* –test for independent samples showed that there is a significance difference in horizontal CCT ($x^2(3)=20.477$, $p=0.000$, s.) and vertical CCT ($x^2(3)=16.700$, $p=0.001$, s.) between the four common living rooms at location A. A Mann-Withney *U*-test for two independent samples showed that living room 5 (location B) appeared to have significantly lower CCT values as compared to living room 1 ($U= 16.0$, $p = 0.005$, s.; $U= 28.0$, $p = 0.039$, s.), living room 3 ($U= 0.000$, $p = 0.000$, s.; $U= 0.000$, $p = 0.000$, s.) and living room 4 ($U= 16.0$, $p = 0.004$, s.; $U= 27.0$, $p = 0.033$, s.) at location A. The measured illuminance levels in common living room 5 at location B were overall lower compared to the measured illuminance levels in the common living rooms at location A (Δ 192 – 880 lux). A Mann-Withney *U*-test for two independent samples showed that living room 5 (location B) appeared to have a significantly lower horizontal illuminance levels when compared to living room 2 ($U= 22.0$, $p = 0.014$, s.) and living room 4 ($U= 25.0$, $p = 0.024$, s.) at location A. Furthermore, the measured illuminance levels in the common living room 2 and 4 of location A were 43% higher compared to the measured illuminance levels in common living room 1 and 3 of location A because of the different orientation of the common living rooms and different time frames (morning or afternoon) of the measurements (Figure 4.1.1).

In general, the recommended values for horizontal and vertical illuminance (750 lux or higher Sinoo *et al.,* 2011; Silverstone *et al.,* 2000) were mainly reached on positions that were relatively close to the window (in the range of 1 to 2 meters). For positions farther away from the window, the illuminance values decreased. The results also showed that the measured CCT values were between 4000 and 5500 K, with some peaks up to 7000 K and mainly determined by daylight. The current electric lighting only had a small or no remarkable effect on the illuminance values (Δ 12 lux – 462 lux) and a slightly diminishing effect on the CCT value (living room 1, 2 and 5). In living room 4 the CCT was lower with the electrical light switched on. This effect was probably caused by the changing weather conditions. The sky was clear with a lot of clouds drifting by. In living room 3 the measured illuminance values were even often higher without the contribution of electrical light. This can be attributed to the fact that most sitting positions of the residents (measuring position) were close to the window; therefore, the residents were more exposed to daylight.

Table 4.1.1: Overview day and electrical light measurements; illuminance and CCT per common living room*

Location	A		A		A		A		B	
Common living room	1		2		3		4		5	
Orientation	South West		South West		North East		South East/ North West		East-North East	
	Daylight	Daylight +electrical lighting	Daylight	Daylight +electrical lighting	Daylight	Daylight +electrical lighting	Daylight	Daylight +electrical lighting	Daylight	Daylight +electrical lighting
Ehor (lux)	646	863	1082	1489	1263	801	1295	1433	514	609
	(U=47.0, P= 0.401, n.s.)	(U=34.0, P= 0.093, n.s.)	(U=37.0, P= 0.138, n.s.)	(U=22.0, P= 0.014, s.)	(U=10.0, P= 0.003, s.)	(U=38.0, P= 0.156, n.s.)	(U=25.0, P= 0.024, s.)	(U=25.0, P= 0.024, s.)		
CCT (K)	5792	5172	4983	4309	6102	6963	5166	5247	4244	4181
	(U=3.0, P= 0.000, s.)	(U=16.0, P= 0.005, s.)	(U=20.0, P= 0.010, s.)	(U=50.0, P= 0.519, n.s.)	(U=0.000, P= 0.000, s.)	(U=.000, P= 0.000, s.)	(U=32.0, P= 0.071, n.s.)	(U=16.0, P= 0.004, s.)		
Ever (lux)	442	558	759	1213	1117	836	1032	1081	643	649
	(U=59.0, P= 0.949, n.s.)	(U=50.0, P= 0.519, n.s.)	(U=45.0, P= 0.333, n.s.)	(U=27.0, P= 0.033, s.)	(U=25.0, P= 0.053, n.s.)	(U=41.0, P= 0.220, n.s.)	(U=46.0, P= 0.366, n.s.)	(U=46.0, P= 0.366, n.s.)		
CCT (K)	5227	4633	4860	7004	5600	6164	5090	4823	4151	3978
	(U=10.0, P= 0.001, s.)	(U=28.0, P= 0.039, s.)	(U=18.0, P= 0.007, s.)	(U=41.0, P= 0.220, n.s.)	(U=4.0, P= 0.001, s.)	(U=0.000, P= 0.000, s.)	(U=16.0, P= 0.005, s.)	(U=27.0, P= 0.033, s.)		

* Average value determined over all measure positions (Location A, July 12th 2012; Location B, April 2nd, 2014)

4.1.4.2 Exploration: findings of the interviews before the intervention

The aim of the interviews was to obtain insight in the perception of the healthcare professionals and related aspects of the lighting conditions that facilitated or restricted their work activities. The analysis of the interviews led to five main themes: perception, control of the light systems, work performance, floor plan, and different types of lighting. Table 4.1.2 gives an overview of the themes which were associated with 14 subthemes .

Regarding perception, ten healthcare professionals of location A gave a neutral response to the lighting conditions in the common living rooms. They judged the lighting conditions in the common living rooms adequate for working and they experienced no hindrance. However, they did mention, as a problem, that the lighting conditions were not always sufficient for reading activities or to perform tasks as cleaning or cooking. Another problem they mentioned was that the current light conditions caused discomfort among the residents. For example, the amount of (day)light in the common living rooms during sunny weather. An important aspect that was mentioned regarding the atmosphere of the lighting conditions in the common living rooms was the wish to create a homelike environment and to be able to use an adjustable light system.

Regarding control, in the common living rooms, no automatic lighting systems were available to regulate the amount of light in the room. The basic light system in the common living rooms were mostly switched on. Four healthcare professionals mentioned that they switched the luminaires on/off as they do at home in the common living rooms as well as in the bedrooms. For example, they switch the luminaires off during daytime to save energy in accordance with their behaviour at home. Switching the luminaires on/off depends on the location of the common living rooms and the amount of daylight in the room.

Regarding work performance, a combination of various factors was seen for incidents, for example, being restless, falls, and aggression. It is unclear if fall incidents are related to the lighting conditions. For the visual tasks the healthcare professionals prefer an adjustable light system for the possibility to change the illuminance level during the day. In addition, in the current situation there is no specific place for staff to perform daily tasks.

Related to the work performance of healthcare professionals is the floor plan of the common living room. In the current situation, the majority of the residents were placed at the dining table. One healthcare professional mentioned that the residents moved to other common living rooms where the lighting conditions were better.

Additional light besides the basic light system is needed to perform visual tasks as wound treatment. Two healthcare professionals mentioned that ambient light is important to create a home environment for the residents. Furthermore, two other healthcare professionals gave the suggestion to change the entire current light system.

Table 4.1.2: Identified themes and subthemes from the interviews with the healthcare professionals (N= 17)

Theme	Subthemes	Results
Perception	Neutral	Ten healthcare professionals judged the lighting conditions in the common living rooms adequate for working. They said: "There is a difference in the lighting conditions. In some common living rooms it feels darker than in other common living rooms. Furthermore, they make a remark about the residents. "It also depends on the preference of the resident."
	Problem	Insufficient artificial light as well as daylight in the common living rooms (N=11). The current light system is not sufficient for reading activities or to perform tasks such as cleaning and cooking.
	Awareness	The healthcare professionals experienced no hindrance from the lighting conditions while they mentioned that the lighting conditions are not always sufficient or create discomfort for the residents
	Atmosphere	The light system has to contribute to the atmosphere of the common living room (N=6). They gave the recommendation to choose an adjustable light system and create a homelike environment and not an office room. The common living room is not a comfortable place to stay. It feels uninviting (N=1).
	Brightness	The amount of (day)light and the temperature in the common living room caused discomfort for the residents and healthcare professionals in sunny weather. In this situation it is necessary to use sunscreens in the common living room. The amount of daylight created discomfort (N=1). Too much light gave discomfort and pain for the resident.
Control of the light systems	Control the light systems	In the common living rooms the healthcare professionals switch the luminaires on/off. Switching the luminaires on/off depends on the location of the living room and the amount of daylight.
	When to switch on/off the light systems	The healthcare professionals switch the luminaires on/off as they do at home (N=4). The basic light system in the common living room is switch mostly on.

Work performance	Incidents	It is unclear if the fall incidents are related to the light situation. Additionally, fall incidents or medical errors are related to different causes. The combination of various factors was seen as cause for incidents, for example, being restless, aggression and obstacles were mentioned.
	Visual tasks	There is no specific place for the staff to perform daily tasks (N=1). An adjustable light system is desirable. Especially, the possibility to change the illuminance level during the day and for activities (N=1).
Floor plan	Situation	The majority of the residents were placed at the dining table near the window zone. In each common living room, the situation is different (N=1). The residents moved to other common living rooms where the light conditions were better (N=1).
Different types of lighting	Basic	For visual tasks such as wound care treatment it is necessary to have extra light besides the basic light system.
	Tasks	Ambient light is important to create a home environment for the residents (N=2).
	Ambient	Change the entire light system in the common living rooms (N=2).
	Light systems	

4.1.4.3 Exploration: the observations; pre conditions

At breakfast, lunch and dinner, most residents were in the living room to eat together near the dining table. The residents spent more time in the living rooms during the weekends because all external activities (hairdresser, physiotherapy, hobbies, etc.) are organised during the weekdays. The residents were free to move around in the psycho-geriatric department on their own floor level. The position of the residents in the common living room was relatively close to the window and is influenced by the position of the furniture and the use of wheelchairs. The activities that were performed in the common living room included: (i) eating, (ii) listening to music, (iii) watching TV, (iv) reading a book or look at photographs, (v) having a conversation, and (vi) sleeping and sitting.

During 25% of all observations, the residents had their eyes closed. When the residents had their eyes open, they looked straight forward the majority of time (62%) instead of downwards or upwards. In 59% of all observations (N=344), they looked parallel to the window. Looking away from the window was observed the least (14%).

4.1.4.4 Evaluation of light measurements and healthcare professionals' perception of the light conditions

Figure 4.1.5 shows the living room with the new lighting plan installed at the ceiling (left) and the reference living room without the new lighting plan (right). Both rooms have the same amount and size of windows but are mirrored. A Mann-Whitney *U* – test for two independent samples showed that the new situation appeared to have a significantly higher vertical (U=17.0, P= 0.038, s.) and horizontal (U=4.0, P= 0.001, s.) illuminance levels and significantly higher CCT values (U=9.0, P= 0.005, s; U=6.0, P= 0.002, s.) as compared to the reference room (see Table 4.1.3). The intervention room had even higher CCT and horizontal illuminance levels in winter when compared to the spring situation (see Table 4.1.1). In addition, the CCT also increased to higher values between 5000 and 6500 K, which is comparable to daylight.

Figure 4.1.5: The common living room with the new light system (l) and in the reference common living room (r).

Table 4.1.3: Overview of light measurement intervention room and the reference room (December 6th, 2014).

Common living room	**Intervention room***		**Reference room****	
	Daylight	Daylight +electrical lighting	Daylight	Daylight +electrical lighting
Ehor (lux)	283 (U=37.0, P= 0.757, n.s.)	874 (U=4.0, P= 0.001, s.)	226	238
CCT (K)	5909 (U=29.0, P= 0.310, n.s.)	6047 (U=9.0, P= 0.005, s.)	4861	4268
Ever (lux)	354 (U=38.0, P= 0.825, n.s.)	548 (U=17.0, P= 0.038, s.)	263	282
CCT (K)	5892 (U=17.0, P= 0.038, s.)	5936 (U=6.0, P= 0.002, s.)	4909	4222

* Waldmann amadea – 2 x 54 C Dali armature (CCT 4000 K; 4450 lm)
** Luminaire with incandescent lamps

The three regular healthcare professionals working in these two common living rooms were interviewed, and they appraised the new situation well. They felt more active in the new situation compared to the old situation. However, they had a few comments about the working of the new light system. They experienced that the new light systems did not work correctly all of the time. In particular, in the evening, there was still bright light in the common living room, which caused more contrast between the common living room and the hallway. Furthermore, the residents were confused due to the bright lighting conditions in the evening and it was hard to get the residents to their bedrooms. After the settling-in process (six weeks), the healthcare professionals appreciated working in the new situation. They also noticed that the residents of the other common living room came over and stayed in the common living room with the new light system.

The results of the observations after the intervention showed that during the day the common living room was almost fully occupied during breakfast, lunch, and dinner. Between the meals the common living room was never fully occupied. In the common living room with the new light system, the illuminance level was higher at approximately 5 PM when compared to the reference room, and more residents were present. The residents of the reference room were located more often in the common living room with the new light system instead of their own room according to the healthcare professionals.. The viewing direction depended on the location of the furniture. A Fisher's Exact Test revealed that there is no significance difference in observations regarding eyes open or closed ($p=0.221$) and eye direction ($p= 0.686$) between the residents in the intervention and reference room (Table 4.1.4). The sitting positions of the residents in the reference room were located more towards the window than the sitting positions in the adapted room.

Table 4.1.4: Overview observations eye open or closed and eye direction in the new setting and reference room (6 residents per common living room) location B per half hour from 09:00 – 17:00 h.

	Common living room	Intervention room	Reference room	Total	Fisher's Exact Test	p-value
Eyes open or closed	Open-upward	0	0	0	Value = 3.019	p = 0.221
	Open-straight forward	36	52	88		
	Open-downwards	6	6	12		
	Closed	4	1	5		
Eye direction	Towards window	8	14	22	Value = 0.779	p= 0.686
	Parallel to window	17	25	42		
	Away from window	18	20	38		
	Total	89	118	207		

4.1.5 Discussion

In this field study, a variety of methods were used in a lighting design process based on the participatory design approach. It was aimed to investigate and formulate the user experience with the physical environment to develop a lighting design plan that suited both residents and healthcare professionals. The three steps in this study gave insight in the lighting design decision-making process based on the perspective of all types of building users. In the following sections, understanding different demands from user groups, decision making in a lighting design process, future studies, and limitations are discussed.

4.1.5.1 Understanding different demands from user groups

The different steps followed in this field study give additional and more detailed information about different user groups with different demands within one joint environmental setting. Understanding the different demands could help the management of healthcare facilities with a validated decision-making process for their real estate strategy (Huang *et al.,* 2013). This study therefore contributes to the existing literature by identifying the

experience of different characteristics of the lighting conditions that could affect health and, well-being by two different user groups of a long-term care facility and showing how to combine different needs in a lighting design for a common living room in such a facility.

This study contributes to the existing literature by exploring the relevancy of light conditions for older adults and healthcare professionals. Improved lighting conditions may lead to benefits for older adults and healthcare professionals in terms of visual and non-visual effects (Boyce, 2010; Sinoo *et al.,* 2011). Moreover, there is a growing body of evidence that comfortable indoor environments (including indoor air, thermal comfort, lighting and acoustics) are related to the quality of life of residents and lead to improvements in productivity in the workforce (Kim *et al.,* 2015; Kort, 2017). The comfort of lighting levels can improve staff effectiveness and eliminate distractions and discomforts (Kim *et al.,* 2015; Van Duijnhoven *et al.,* 2017). Even though the results of this case study are related to only one common living room and one particular location, they are in line with findings from the literature in hospitals and office environments. The improved illuminance levels influenced the experience of the lighting conditions of the common living room by the healthcare professionals and residents. More residents were present and the residents seemed to be more active in the new situation, for example, talking and reading instead of sitting and looking around according to the healthcare professionals.

Another innovative aspect of this field study is that it used qualitative subjective data to obtain in-depth information on the different perceptions of the lighting conditions. The on-site observations proved to be a useful method to gain insight in the behaviour of older people who suffer from psycho-geriatric disorders in the design and development process. It is especially important to involve them, because this target group is one of the main users of long-term care facilities (Joseph *et al.,* 2016). The obtained results of the observations (view direction, eyes open or closed) were relevant input for the determination of the positions of the new luminaires in the common living room. From the qualitative subjective data, it was possible to develop and realise a non-pharmaceutical light-based intervention that supported both the preferences of the healthcare professionals and the behaviour of the residents. This shows the relevance of the involvement of users in a design and development process via a participatory approach (Abras *et al.,* 2004; Kang *et al.,* 2015).

Last, this study contributes to existing studies by combining quantitative physical measurements and qualitative subjective assessment, which provided a more holistic approach of users' perspective and more detailed information. Additionally, it is the first study to test existing knowledge in the setting of a long-term care facility. As this asked for a multidisciplinary approach and required knowledge of both fields (health and light),

collaboration between researchers and experts from both fields was important.

4.1.5.2 Decision making in a lighting design process

Understanding different demands from user groups creates the possibility to obtain a better understanding of the consequences of design decisions for the primary process of care giving. The findings in this field study give long-term care organisations more foundation for their real estate design decisions. Long-term care organisations can apply this bottom up approach themselves to obtain more detailed information on the special needs and expectations of the different user groups and where the needs and expectations possibly conflict with each other. For this approach, the healthcare professionals and residents acted as co-developers and their input was a relevant source of information for decision making at the operational management level and how the decision contributed to the core business drivers of the organisation.

In addition, the results show that lighting conditions could be a potential steering mechanism in healthcare real estate decisions. Board members, corporate real estate managers and facility managers should be more aware that it is necessary to translate the current light guidelines to their target groups and thus align their thoughts and ideas in a joint decision-making process. Due to development and realisation of the light design intervention the organisation obtained insight in the lessons learned and critical steps during the process. The facility manager of the long-term care facility became more aware of the consequences of their lighting design decisions for the residents and healthcare professionals. This is shown because the organisation changed their programme of requirements for their entire building portfolio based on the findings of this study. Furthermore, it was useful to determine the next steps for the organisation regarding the renovation of the buildings.

The case study organisation had the ambition to create an enriched environment for the residents and healthcare professionals in their mission statement. With this they meant to represent an organisation that focuses on care and the physical environment of the residents and healthcare professionals to support well-being. For long-term care organisations, it is important to develop their core business drivers and their real estate decisions in cooperation with their important user groups. Structural meetings together with all relevant stakeholders (e.g., client board, healthcare professionals, facility staff members, suppliers of equipment, and interior architects) are important to share the results of the different steps and become aware of each other’s expectations and needs.

4.1.5.3 Limitations/ Future studies

This field study has certain limitations. For example, the emphasis was placed on the lighting conditions in common living rooms only, but all interviewed healthcare professionals also mentioned insufficient lighting for wound care treatment in the bed and bathrooms. To perform visual tasks and to prevent mistakes such as medication errors, it is important to apply a complete lighting system (Aarts and Kort, 2017). Future studies could investigate the lighting conditions in bed- and bathrooms of long-term care facilities. Another limitation is that the light measurements occurred during the daytime. It could be interesting to follow the steps of this study in a 24-hour setting. In addition the light measurements were limited to the horizontal and vertical illuminance and the correlated colour temperature but it is useful to take into account the coloring rendering index (CRI) and the spectral power distribution for the luminous environment in future studies too. The view outside and the influence of windows (size and number of windows) were also excluded in this study, but it could be relevant to take these aspects into account as well in relation to job performance, satisfaction, and quality of life (Dianat *et al.,* 2013; Duijnhoven *et al.,* 2017). Despite the fact that the illuminance levels in the adapted room were increased, no account was made with the possible effect of the white panels on the whole ceiling on the illuminance levels and CCT values. The effect depends on the reflectance of the white panels. To realize the recommended effect of the white panels, it is necessary to determine the luminance distribution.

Another important factor in the decision making for the lighting design of the common living room was the position of the furniture in the room. In this study, the position of the furniture in the common living room often changed and the position depended on the activities in the common living room. This resulted in a homogenous lighting design for the common living room. So, in future studies the healthcare professionals' need to have the possibility to arrange furniture aligned with the executed activities and seasonal influences could also be included.

Ten healthcare professionals judged the lighting conditions in the common living rooms as adequate for working tasks. However, by asking more in-depth questions they gave more critical remarks such as: *"some common living rooms feel darker than other common living rooms".* For future research, it could also be interesting to consider the awareness of healthcare professionals regarding the influence of multiple indoor environmental factors (e.g., light, noise, ventilation, and temperature) on the comfort of the residents and the consequences for daily functioning and alignment of basic care of the resident. In addition, how to find the optimum between these indoor environmental factors and the expectations

of the users is an interesting topic for study.

For future research, it could also be interesting to add a client record screening to provide information on the residents' general health conditions. For the client record screening it would be preferable to give healthcare professionals clear instructions for reporting in the client records to obtain detailed information about the adapted circumstances and the influence on the residents (e.g. categories as mood, medication, eating behaviour and sleep behaviour).

Last while, this study focused on operational management, in future research, the dialogue between strategic management and operational management is relevant to study as well for obtaining more insight into the decision-making process in long-term care facilities to create added value with real estate for residents and healthcare professionals.

4.1.6 Conclusion

This case study described a bottom-up approach to define the lighting conditions from both resident and healthcare professionals perspectives in a Dutch long-term care facility. The modified light system plan in this study demonstrated that the light conditions were improved. The structural approach taken in this field study show that it is valuable to identify the experiences from different perspectives regarding the lighting conditions and the quality of the lighting conditions itself and use the findings in the design decisions for redesign of the nursing home. Combining the experiences of different user groups is a valuable source of information in a dynamic and complex design process such as renovating a long-term care facility.

Subchapter 4.2: Redesign of the acoustical climate in a nursing home

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Abstract

Purpose In this case study the focus is laid on the acoustical climate as potential indoor environmental aspect that contributes to organizations' ambition and real estate strategy. Currently, it is unknown how corporate real estate managers or facility managers can use functionalities in the physical environment to support their real estate strategy. The aim of this case study is to describe the steps in order to make the optimum real estate decision based on the best available evidence for the acoustical climate in nursing homes to add value for their users. **Method**. Two locations (A and B) of a nursing home organization were selected to execute the following steps (i) acoustic measurements, (ii) interviews with healthcare professionals before the intervention, (iii) the development and realization of an acoustic intervention, and (iv) an evaluation of the intervention via acoustic measurements and interviews. **Results and Discussion** The acoustic measurement showed a difference in the averaged reverberation time and background noise levels measured at location A and B. All healthcare professionals mentioned that the room acoustics at both locations were acceptable. However, the healthcare professionals at location B mentioned they experienced the living rooms as acoustically hard, which implies a relatively long reverberation time. Therefore, the intervention was conducted in one of the living rooms at location B. The evaluation of the intervention showed a decrease of 50% in reverberation time and an 0.12 increase of the speech transmission index. The healthcare professionals (location B) remarked that they felt more comfortable and less tired and according to the professionals, the residents seemed more comfortable in the living room at location B. The findings show that an intervention to enhance the acoustical climate in nursing homes, has a positive effect on healthcare professionals and residents. In this case the decision was made by the board members of the organisation to renovate all living rooms at that particular location aligned with the chosen intervention.

Keywords

facility management, corporate real estate management, health, speech intelligibility, sound sources

4.2.1 Introduction

Aspects of the indoor environment are one of the steering mechanisms for real estate decisions. However, it is a challenge for corporate real estate managers and facility managers to make real estate decisions based on indoor environmental factors (Van der Voordt, 2016; Lindholm and Leväinen, 2006). A clarification could be that it is unknown how aspects of the indoor environment can contribute to core business drivers such as increased client satisfaction or increased productivity of healthcare professionals.

In this case study the focus is laid on the acoustical climate as a potential indoor environmental aspect that contributes to organisations' ambition and real estate strategies. The international classification of functioning, disability, and health (ICF) provides an overview of various aspects of health conditions in terms of influencing activities of biological, personal, environmental, and social factors (WHO, 2002). Within the ICF model, the indoor environment (e.g light, acoustics, indoor air) is seen as an environmental factor. In this case a focus is laid on the acoustical climate, the facility managers and technical staff can adapt the indoor environment and systems to improve the residents' and healthcare professionals' environment. All this could enhance the client and employee satisfaction of the residents with hearing problems.

The acoustical climate in a Dutch nursing home was measured to gain insight into the added value of the acoustical climate regarding healthcare professionals' work perception and the well-being of the residents. The aim of this case study is to describe the current acoustical climate and to examine how to enhance the acoustical climate in the nursing home in terms of residents' quality of life and the well-being of the healthcare professionals. Furthermore, steps to take real estate decisions with the acoustical climate as a case are elucidated. This case study is part of a larger project on how the indoor environment affects the well-being of healthcare professionals and quality of life of older people with a frail health condition. This project focuses on the alignment of real estate decisions in relation to building performance of nursing homes.

4.2.2 The acoustical climate in nursing homes

The acoustical comfort of buildings is the capacity to protect users from noise and to offer an acoustic environment that is suitable for the purpose of the building it is designed for (Al horr *et al.,* 2016). The indoor sound environment is determined by room acoustics and sound sources (like music, traffic, HVAC systems, or the presence of distant people). Important acoustic parameters are the reverberation time and background noise level. Both

parameters influence the speech intelligibility in the room (Wenmaekers *et al.,* 2009). The reverberation time of a room characterizes how long acoustic energy remains in a room. While the influence of the acoustical climate and room acoustics are considered as an important factor in building design (Al horr *et al.,* 2016), in our reading of the literature other targets group such as older people with a frail health condition residing in nursing homes are under-represented.

The acoustical climate in nursing homes could be a barrier for residents as they are more sensitive to the noise in their environment (van Hoof *et al.,* 2010). For example, hearing loss can cause problems in understanding speech and holding conversations in noisy environments (Hout *et al.,* 2014). For the acoustical design of rooms, where social interaction takes place, the speech transmission is relevant to be taking into account. Moreover, it is known that noise can cause stress, sleeping and behavioural problems amongst residents in nursing homes.

Reduced noise levels in healthcare facilities have also been associated with reduced stress, reduced emotional exhaustion and burnout, reduced fatigue, increased satisfaction, increased effectiveness, increased productivity (Bayo *et al.,* 1995; Ulrich *et al.,* 2008; Beyea, 2007) and improved communications and decreased medical errors (Zun and Downey, 2005; Joseph and Ulrich, 2007). Additionally, improved acoustical conditions have been linked to a reduction in work demands experienced by healthcare professionals, as well as reported pressure and strain (Blomkvist *et al.,* 2005). The above mentioned studies showed that for both user types, the residents and healthcare professionals, the acoustical climate is an important indoor environmental factor that should be considered in the initial phase of the design process. However, there is still limited research focusing on the effects of room acoustics on healthcare professionals and their caring tasks. The WHO defined general guidelines for acoustical climates, but none are specifically defined for older people with a frail health condition or residents in nursing homes (Berglund *et al.*, 1999). Therefore, there is a need to examine the interaction between the indoor environment for nursing homes and the residents and healthcare professionals. A better understanding will support facility managers and corporate real estate managers in the operationalisation of their real estate decisions.

4.2.3 Methods

4.2.3.1 The study setting

This case study was performed at a Dutch nursing home organization in the western part of the Netherlands. This nursing home organization had the ambition to enhance employee and client satisfaction through increasing the environmental quality. For this ambition, theories such as the healing environment concept, Plane Tree, Mayo Clinic or Eden Alternative, can be used to determine relevant aspects to focus on in the real estate strategy (Kort, 2012) . Based on these theories the aspects, lighting, acoustics and indoor air quality were selected by the board of the organization to be investigated and improved to increase the quality of their buildings. In this case study the aspect acoustics was elaborated. Two locations of the nursing home organization were examined to see how the acoustical climate could contribute to residents' quality of life and support the wellbeing of healthcare professionals (Figure 4.2.1). Location A is a 4 floor building with three wings. Location B is a single floor building. In total, nine living rooms were assessed in this case study (seven in A and two in B). The living rooms for the assessment were selected in corporation with the staff and based on the availability to execute acoustic measurements. The lay-out of the nursing home is such that six bedrooms are connected to one living room, a so called small living facility. During daytime, residents use the common living room that is connected to their bedrooms. Each living room has an open-plan kitchen, a large table, and a small seating area with a television. During the day, two staff members, including nurses, are available per living room.

Figure 4.2.1. Location A (L) and Location B (R); two examples of a floorplan. The measurement point is denoted in red.

4.2.3.2 Study Design

In this case study the following steps were taken: (i) acoustic measurements to measure the current acoustical climate condition, (ii) interviews with healthcare professionals, (iii) selection, development and realization of the intervention, and (iv) evaluation of the intervention. In the following sections the steps are described in more detail.

Step 1: Acoustic measurements

To describe the room acoustics of nine living rooms (7 in A and 2 in B) the following parameters were used: background noise level, reverberation time, and the speech transmission index (STI). The STI is an objective measurement predictor of speech transmission quality and is, amongst others, influenced by room acoustics. These measurements were performed according to ISO 3382-2/3 and IEC 60268-16 in an unoccupied situation. Depending on the lay-out of the living rooms the STI was derived from measured impulse responses between 9 to 13 source and receiving points. Besides the measurements in all common living rooms an inventory of the acoustic finishes of all rooms was made.

Step 2: Interviews with healthcare professionals

Further information regarding the living rooms was obtained through interviews with healthcare professionals. The aim of the interviews was to get insight in the perception of the healthcare professionals on their well-being and factors facilitating or restricting their work activities related to the sound environment. Twenty-two healthcare professionals were invited by the team leader of the location to participate in the interviews. The healthcare professionals worked in different locations in different acoustical climates. They received a letter in which a clear description of the study was provided. In total nineteen healthcare professionals were willing to participate in the study. Seventeen healthcare professionals were women and two healthcare professionals were men (age range: 22 to 61). The interviews were held at both locations. The interviews took place at the workplace of the respondents. The topic list was developed together with the national organization for applied research TNO and based on the expertise of the research team. The topic list was pilot tested with students. All interviews were audio-recorded with the permission of the participants and were transcribed and entered into MaxQDA version 12. First, each transcript was read in its entirety. Then, they were read a second time to develop codes. Defining the codes was done through two processes of open coding and axial coding (Boeije, 2010).

Step 3: Selection, development and *realization of the intervention*

Intervention decisions were based on the outcomes of the acoustic measurements, interviews with healthcare professionals, an acoustic expert (2nd author), and the board of the healthcare organization. Based on the findings in step one and two location B was selected for the intervention. At location B two mirrored living rooms next to each were part of this study; one served as a control location (no-intervention) and in the other an intervention was conducted. The analysis of the measurement results of location B showed in this case the STI was mainly dependent on the reverberation time (RT) and not on the background noise level. The RT of both living rooms, averaged over the octave bands 125 Hz – 2000 Hz, was 0,86 s. The goal of the intervention was to see how much the STI would improve by reducing the RT by factor 0,5. A 3D raytracing model was used to determine the amount of sound absorbing material required to reach this reduction. The intervention contains the usage of 35 m^2 sound absorbing material. For the sound absorbing material the Ecophon solo rectangle panel in the size 2400 x 1200 x 40 mm with a weight of 11,5 kg was used. In total, twelve panels were positioned at the ceiling of the living room with an air gap of 200 mm between the panels and the ceiling.

Step 4: Evaluation of the intervention via acoustical measurements and *interviews*

After the intervention, room acoustic measurements (step 1) were conducted again to determine the effect of the intervention on reverberation time and STI. Additionally, interviews were held with the two healthcare professionals regularly working in the adapted living room to gain insight in the impact of the intervention on their well-being and performance. To gain more insight into the decisions a non-structural interview with the facility manager of the organization was held.

4.2.3.3 Ethics

In the organization, it is the policy to inform the client board about any research project. The client board approved the research project. Furthermore, the managers of the organization agreed on the measurements from the start of the project and were involved in the planning of the project. The professionals and family carers, along with the residents, were informed about the measurements. Daily activities were not disturbed nor hindered by the measurements procedure.

4.2.4 Results

In the following sections, the outcomes of the acoustic measurements, interviews and the intervention are described.

4.2.4.1 The acoustic measurements

The averaged reverberation time of the living rooms of location A was approximately 0.2 s shorter compared to the living rooms of location B. Furthermore, the results showed a difference in the measured background noise levels in an unoccupied setting. The averaged background noise level of the livings rooms of location A was 5 dB higher than the measured level in the living rooms of location B. See Table 4.2.1. Although the determined speech intelligibility index of the livings rooms of location A and B was almost equal a difference in the acoustic climate between the living rooms at location A and B was measured.

Table 4.2.1: overview of the acoustic assessments

	Location A (N=7)	**Location B (N=2)**
Reverberation time $T_{20,gem}$	0,67s	0,86s
Background noise L_{aeq}	41 dB	36 dB
Speech intelligibility index (STI)	0,62*	0,63*

* Average value determined over all source and receiving points.

4.2.4.2 The interviews

The analysis of the interviews led to three main themes: sound sources, speech intelligibility and, reverberation. These themes were associated with six subthemes. See Table 4.2.2. The perception of the acoustical climate at location A and B confirms the measured difference in the reverberation time. The healthcare professionals mentioned that the living room at location B was acoustically hard and mentioned reverberations. Although the living rooms at location B were acoustically hard, the healthcare professionals said that they experienced no hindrance from various sound sources. The sound sources in the living room were mainly caused by the activities of residents and healthcare professionals like: listening to (live) music, watching TV, moving chairs, cooking, and cleaning.

Table 4.2.2. Identified themes, subthemes, and results before the intervention

Location	Theme	Subthemes	Results
Location A	Sound sources	Music/TV	Two healthcare professional mentioned that they use the radio daily. In the morning they use the radio to give the residents a good start of the day. Sometimes residents asked to turn the volume of the music. This could be related to their hearing aids. Another argument to use the radio was to break the silence in the living room.
		Contact noise	Eleven healthcare professionals mentioned that moving the furniture caused contact noise. This is clearly audible between the different floors. One healthcare professional mentioned the music between the bedrooms was audible but it was not experienced as a hindrance. This sort of noise belongs to the daily routine.
		Environmental noise	Six healthcare professionals mentioned that they experienced no hindrance from environmental noise coming from outside of the building. One healthcare professionals said "*the residents were more disturbed by each other than by other sound sources".*
		Background noise	Two healthcare professionals mentioned the cooker hood as disturbing sound. It causes distraction and restlessness by the residents. One healthcare professional gave the height of the living room as an argument for background noise. Another professional was disturbed by comings and goings of people.
Location A +B	Speech intelligibility	Have a conversation	Nine healthcare professionals experienced no difficulties regarding the communication with residents. The healthcare professionals related communication problems to the voice, the health condition of the resident, the stage of dementia, and the volume of the music.
Location B	Reverberation time	Reverberation	Two healthcare professionals mentioned the reverberations in the living room caused by the height of the living room.

4.2.4.3 The acoustic measurements and evaluation

Figure 4.2.2 shows the living room with the sound absorption panels installed at the ceiling (left) and the living room without the sound absorption panels at the ceiling (Right). The colour of the sound absorption panels are white (left), while ceiling in the control living room (right) is wood. The results of the intervention showed a decrease of 50% in reverberation time and an increase of the STI of 0.12 (Table 4.2.3).

Figure 4.2.2. The living room with sound absorption panels (L) and the control living room (R).

Table 4.2.3. The Speech Intelligibility Index before and after the intervention.

	Before intervention	**After intervention**
Reverberation time $T_{20,gem}$	0,86s	0,44s
Speech intelligibility index (STI)	0,62	0,74

The two interviewed healthcare professionals received the new situation well. They experienced that the reverberation was less than before. They said: “there is an obvious difference between the two living rooms next to each other”. The healthcare professionals gave remarks about the living room being more quiet and peaceful. They said: “I felt less tired than in the other living room”. Another remark they made was: “I can do my work better”. In addition, the healthcare professionals can have a conversation with the residents in more comfortable way. Also, they mentioned that the residents were more comfortable in

the new situation in their opinion.

Another aspect mentioned by the healthcare professionals was related to the colour of the sound absorption panels of the living room. As the panels where white, it seems brighter in the living room. They made the following remark: “It is not necessary to switch on the lights to distribute medication. I can read the list with medication better”.

4.2.5 Discussion

The four steps of this study show the process of making a real estate decision regarding the acoustical climate in a nursing home based on best available evidence and from the perspective of the user. In the following sections, understanding the interaction between the environment and user and added value for residents and healthcare professionals are discussed.

4.2.5.1 Understanding the interaction between the environment and users

Understanding the physical characteristics of the indoor environment that affect health, comfort, and wellbeing is the key requirement underpinning the beneficial design of nursing homes (Salonen *et al.,* 2013). Additionally, it is important to understand the physical characteristics that are most likely to optimize individual physical, mental, and emotional well-being (Salonen *et al.*, 2013). From the literature it is known that environmental factors such as temperature, noise, and lighting are related to the quality of life of the residents (Garre-Olmo *et al.,* 2012). Even though our results relate to one living room and a particular location, they are in line with findings from the literature. The shorter reverberation time and improved STI positively influenced the experience of the acoustical climate of the living room by the healthcare professionals. Especially, in supporting the daily activities and increasing the communication between the healthcare professional and residents. Bradley *et al.,* (1999) described in their study that the just noticeable difference of STI is 0,03. The just noticeable difference is the smallest difference that a person recognize a variation in sensory experience (Bradley *et al.,* 1999). In this study the STI is increased with 0,12 and the two interviewed healthcare professionals regularly working in the adapted living room describe a difference in sensory experience as well. These results should be validated in further research. Therefore, it is relevant that future studies should investigate the acoustical environment of multiple nursing homes in order to define sufficient acoustical guidelines to prevent speech intelligibility issues among residents as well as healthcare professionals in nursing homes to support them in their daily activities. In this

study, the acoustical measurements (before and after the intervention) and the interviews with healthcare professionals were useful to get insight in how the acoustical climate contribute to residents' and healthcare professionals' well-being in order to do an intervention, and the design of the intervention is dependent of different variables of the particular locations. In addition, the measurements (before and after the intervention) gave insight in how the acoustical intervention could support to the daily activities of the healthcare professionals and residents. The results of the intervention confirms these finding. This study might be used as starting point for the discussion to increase the awareness of the physical characteristics of the indoor environment that contribute to quality of life of the residents and well-being of the healthcare professionals. Furthermore, facility managers or corporate real estate managers should be aware that current acoustic guidelines are not specifically developed for older people with a frail health condition.

While this study give insight in the added value of the acoustical climate regarding healthcare professionals' perception and well-being of the residents the focus was laid on the reverberations and speech intelligibility. More research in the field of perception and annoyance caused by noise among older people and nursing home staff should be conducted to get a better understanding between the environment and users.

4.2.5.2 Added value for residents and healthcare professionals

In this study three relevant real estate decisions were taken in cooperation with the nursing home organisation. First, the nursing home organisation define their ambition to increase well-being and comfort of their residents and healthcare professionals through adaption of their real estate. The second decision was to enhance the quality of their building via building physics interventions with the emphasis on acoustics. The last decision was to adapt one living room based on the outcomes of the measurements and interviews. Decision one and two can be described as strategic management decisions and these decision are often based on the core business drivers of an organization. The third decision is an operational management decision and is more specific. The four steps in this study gave valuable information and input for the last decision to develop an acoustical intervention and implement this. Furthermore, the steps taken in this study gave also valuable information how to develop an intervention for the other indoor environmental aspects (like light and indoor air quality) from the residents' and healthcare professionals' perspective. Moreover, these steps gave relevant input for the decision making process and the realisation of the intervention for the corporate real estate manager and facility manager. The three decisions are needed to have a constant dialogue between strategic management and operational management to create benefits for the healthcare professionals and residents

(Ali *et al.,* 2008). Although this study focused on the last decision, in future research the dialogue between strategic management and operational management could be investigated.

Furthermore, the findings of this study contributed to evidence-based design (EBD). The aim of EBD is to systematically translate research findings into design practice and to expose the best available evidence in order to help facility members, corporate real estate managers and designers to make design decisions based on users' needs (Marquardt *et al.*, 2014; Pati, 2011; Stichler, 2010). The improvement of the acoustical climate at a particular location in this case study may lead to a better understanding of the physical characteristics of the indoor environment and real estate decisions that contribute to the ambition of the healthcare organisation which include an indoor environment that increase the comfort and wellbeing. However, it is still complex to quantify indoor environmental parameters for the entire nursing home organization. This is because the conditions and the perception per location is different. Therefore, it requires insight in the current conditions per location and it is necessary to gain information which parameters for redesign were relevant for each location. In addition, the interaction with the healthcare professionals and other stakeholders were important to provide guidance for design and to achieve the optimum indoor environment for all users of the nursing home organization (Salonen *et al.*, 2013; Nimlyat and Kandar, 2015). Further research could be aimed at investigating the integrated effect of single environmental factors on the resident's and healthcare professionals comfort and satisfaction (Nimlyat and Kandar, 2015). To define relevant aspects how the building or location affect human health and wellbeing the operational level of the indoor environment should be elaborated.

4.2.6 Conclusion

The steps taken in this case study showed that it is valuable to look at both, the acoustic measurements and the perception of the healthcare professionals and residents. The results showed that a small difference in the acoustical climate led to a benefit for the healthcare professionals and residents. The obtained results of this research show that the acoustical climate should be one of the factors to be taken into account in healthcare real estate decisions. The obtained results of this research can be used as starting point for further research.

Subchapter 4.3: Assessing the indoor air quality of nursing homes

This subchapter is based on the following paper published in International Society of Gerontechnology; special issue Healthy environments. ISSN: 1569-1101 EISSN: 1569-111X

te Kulve, M., Loomans, M.G.L.C., Huisman, E.R.C.M. and H.S.M. Kort. (2017), "A systematic approach to assessing indoor air quality of long term care facilities", *Gerontechnology*, Vol. 16 No. 4, pp. 224- 238, Doi: 10.4017/gt.2017.16.4.004.00.

Abstract

Not much is known about the favourable indoor air quality in long term care facilities (LTCFs), where older adults suffering from dementia live. Older adults, especially those who suffer from dementia, are more sensible to the indoor environment. However, no special requirements for the indoor air in long term care facilities exist. Due to the decrease in cognition function, it is hard to evaluate comfort and health in this group. Nevertheless, infectious diseases are a persistent problem. Based on literature an assessment methodology has been developed to analyse LTCFs to determine if differences in building characteristics and Heating, Ventilation and Air Conditioning (HVAC) systems influence the spread of airborne infectious diseases. The developed methodology is applied in seven long term care facilities in the Netherlands. After that, the methodology has been evaluated and its feasibility and applicability are discussed. From this study, it can be concluded that this method has potential to evaluate, compare LTCFs, and develop design guidelines for these buildings. However, some adjustments to the methodology are necessary to achieve this objective. Therefore, the relation between the indoor environment and infection risk is not yet analysed, but a consistent procedure to analyse this link is provided.

Keywords

indoor air quality, infection prevention, older adults, well-being

4.3.1 Introduction

The number of older adults in the world is increasing rapidly (WHO, 2013). This goes together with sensory changes and increased risk of age related diseases like dementia (van Hoof et al. 2010). Frail older adults suffering from dementia often need institutional care and therefore live in long term care facilities (LTCFs). In these facilities, they spend most of their time indoors (95%) (Almeida-Silva *et al.,* 2014). Additionally, older adults, especially those who suffer from dementia, have an altered sensitivity to indoor environmental parameters (van Hoof *et al.,* 2010). Since the physical environment directly influences health and wellbeing, careful attention to the indoor environment in LTCFs is desirable. The indoor air quality, contaminations, and pollutants as well as temperature, influence the health of occupants in a room (Wargocki *et al.,* 2002). Indoor environmental standards are based on the perception of average people whereas older adults are known to have a different sensitivity of the physical environment (Anderson *et al.,* 2012; Bae and Park, 2009; Norback, 2009). However, there are no special requirements for elderly care facilities (Kort, 2012), while the sensitivity to the indoor environment is even larger for older adults coping with dementia and who live in these care facilities (van Hoof et al. 2010). Therefore, we aim to set up a systematic approach to defining favourable conditions for LTCFs.

Little is known about the current indoor climate in LTCFs, although the effect of the physical environment on the health and well-being of patients has been proved to be important (Huisman et al. 2012). A study in care facilities in Portugal showed that the indoor concentration of CO2, tVOC, O3, and PM10 all exceeded the limits due to insufficient ventilation (Almeida-Silva et al. 2014). A second study found that the mean PM2.5 of 22 elderly care centres was above international reference level during both summer and winter (Mendes *et al.*, 2015). According to Aminoff (2007) poor indoor environmental conditions may have a role in the suffering of people with dementia. By adjusting the indoor environment to the needs of the residents, it is expected they put less demand on the professionals working in the LTCFs. The study of Bae and Park (2009) confirmed in line with previous studies, that older adults are more likely to be affected by air pollution. Indoor air pollution can cause among others cardiorespiratory diseases and asthma (Brugha and Grigg, 2014). Also overheating in buildings goes together with health effects. This is especially important in nursing homes because older adults are at risk to high temperature (Marmor, 1978). On the other hand, cold temperatures may potentiate respiratory tract infections (Mendes, 2015). Apart from the fact that a poor indoor air quality can cause health problems, air can also transfer pathogens of airborne diseases. The study of Li *et al.* (2007) emphasized the need for an investigation on the impact of indoor air onto the spread of airborne infectious diseases, as little is known about the impact of airflow patterns on infectious

disease propagation.

The transmission of infections is complex, and controlling the infections, especially at the psycho geriatric (PG) departments of LTCFs is hard because residents can freely interact with each other and live close together. In addition, staff and visitors have an easy access to the ward. Older adults are more at risk to an infectious disease (Siegel *et al.,* 2007). This is due to the fact that advanced age is related to a declining immune system and a weakened host defense. Illness is often recognized after it has already spread, because of subtle presentation of the infection. However, delays in diagnosing and treating infections increase the risk of transmission within the facility (Garibaldi, 1999). Besides, it is hard to apply restrictions for residents because they do not comprehend the situation (Siegel *et al.,* 2007). Therefore, prevention of infections and outbreaks in LTCFs is important.

There are many studies that suggest that an insufficient amount of ventilation contributes to the spread of airborne diseases but no minimum ventilation rate is known (WHO, 2009). The reason for the little evidence is first of all due to the large number and interacting factors that contribute to the transmission of the infections and the fact that the (airborne) evidence of the airborne infection rapidly disappears once the infection period is over. So, the influence of the ventilation impact is often too difficult to be quantified (Li *et al.,* 2007). The airborne route will become more important when the other routes are blocked. Still, it is not known how much reduction of the contaminant concentration is required, to achieve a measurable reduction in disease transmission (ASHRAE, 2012). The contribution of the airborne route compared to the contact route is yet to be defined due to its complexity. Although there is not much evidence, the contact route is assumed as being the most important. Beggs (2003) concluded that the contribution of the airborne route is likely to be greater than expected due to the movement of contaminated persons, though contact spread is the principle route of most infections.

Additionally, a poor indoor air quality can also contribute to a weakened host as it influences the healing process, recovery, and well-being (Norback, 2009). Apart from the state of dementia, these individuals are a weakened host that makes it more likely for infectious agents to invade (Chohan, 2001). So apart from airborne transmission, the indoor air quality may also play another role in the infection by weakening the defense mechanism of individuals.

Based on an airborne infections disease risk model, filtering (particularly MERV 13-16 filters) was estimated to reduce the risk of infectious diseases compared to equivalent outdoor air ventilation (Nielsen, 2012). Li *et al.* (2007) concluded that there is sufficient and strong evidence that demonstrate an association between ventilation and air movements in buildings and the transmission spread of infectious diseases indoors. Brankston *et al.* (2007)

also state that control of airborne transmission requires control of airflow through ventilation. Building characteristics should be taken into account as well, as they affect bacteria, fungi, temperature and relative humidity measured in elderly care centres (Mendes *et al.,* 2014).

We can conclude that older adults suffering from dementia have different needs concerning the indoor environment and that they are at risk of infectious diseases. Still, there are no specific guidelines for the design of these indoor environments where older adults suffering from dementia live. This is probably due to the lack of knowledge about the desired conditions. Therefore, there is a need to define appropriate requirements for LTCFs. The objective of this study is to provide a systematic approach to developing design guidelines for the indoor climate in LTCFs and to benchmark these buildings. The systematic approach should be able to assess the indoor air quality in LTCFs and its effect on the spread of airborne infectious diseases. This paper describes the development of a systematic approach that can be used to set up indoor climate guidelines, which should reduce the transmission of airborne agents in LTCFs and with that the occurrence of infectious diseases in such facilities.

4.3.2 Methods

In the current study, a systematic approach has been developed to evaluate and compare LTCFs. This approach is based on the scheme illustrated in Figure 4.3.1, which shows the relation between on one hand the building and indoor air quality and on the other hand outbreaks of infections and health and comfort. As shown in Figure 4.3.1, the building characteristics may influence as well the contact as the airborne transmission. The building also affects the indoor air quality; indoor environment measurements may reveal the contribution of the indoor air quality to airborne transmission. General health and comfort aspects are also incorporated because the indoor air quality has an impact on these as well and with that the potency for developing an infection disease. To deduce the role of indoor air in the transmission of infections, the four “categories” in the scheme will be analysed systematically.

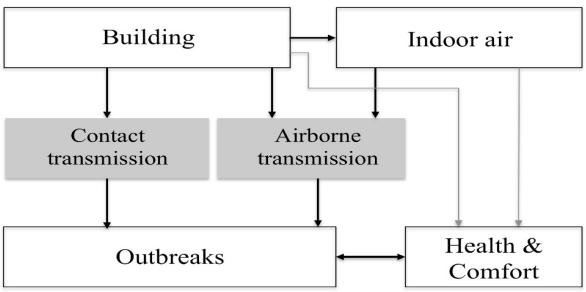

Figure 4.3.1. Scheme factors influencing airborne transmission in LTCFs

4.3.2.1 Literature search/ define contributing parameters

To define the variables that play a role in the outbreak of infectious diseases, a literature search was done to find contributing factors to transmission. The objective of this literature search was not to provide a thorough literature review but to find the building and indoor air parameters that influence the transmission of airborne infections. Also parameters to measure and compare outbreaks of infections in LTCFs were of interest. The electronic databases that were used are Scopus, Science Direct, Google Scholar, Psychinfo and the database Eindhoven University of Technology. The search terms that were used are a combination of '*Dementia*' or '*Psycho Geriatric*' or '*PG patients*' or '*Elderly Care*' and '*Indoor Climate*' or '*Air Quality*' or '*Indoor air*' or '*Design Guidelines*' or '*Healing Environments*' or '*Physical Environment*' and '*Spread of disease*' or '*Airborne diseases*' or '*Indoor Air Quality*' or '*Scabies*' or '*Influence*' or '*Skin flakes*' or '*Mites*' or '*Transmission*' or '*Elderly care*' or '*Long term care facilities*' or '*Psychotherapy*' and '*Behavioural problems*' and '*Assessment*' and '*Treatment*' and '*Systematic Review*'. Additionally, references found in publications were used. In total, out of 37 articles identified, results of 13 articles were used. Titles and abstracts were used to determine whether the papers included relevant information concerning the spread of airborne diseases, influencing factors of transmission, indoor air quality in LTCFs and the sensitivity of older adults to indoor air quality.

4.3.2.2 Systematic approach

The selected publications have been used to define the parameters that might contribute to the transmission of airborne infectious diseases. These parameters are listed in Appendix I. For each of these parameters it has been defined whether it contributes to the airborne and/

or contact route and its reference(s) are added. To compare the outbreaks of infections in different LTCFs, the size, frequency, type, period and duration of the outbreaks were defined as parameters. For health and comfort, a list of variables has been composed as well. These are incorporated into a set of questions for the health care professionals. The set of questions include work schedule and activity related questions, questions about the general feeling of health, comfort, and control over the indoor climate. The Health Optimisation Protocol for Energy-efficient Buildings (HOPE) study (HOPE, 2018) has been used to set up the structure of the evaluation of the building characteristics.

4.3.2.3 Application and evaluation of the systematic approach

To verify whether the systematic approach is suitable to analyse the relation of indoor air and the outbreaks of infections, it was tested in seven LTCFs in the Netherlands. This was done at the psycho geriatric (PG) department of the tested LTCFs. The buildings needed to be at least three years old to be included in the study, so the history of infectious diseases could be analysed. The basic characteristics of the buildings that were studied are indicated in Table 4.3.1.

Table 4.3.1: Basic characteristics of the LTCF's participated in study

Building	Year built	Operable windows	Mechanical ventilation	Nr of residential groups	Nr. PG patients	Size [m^2] (PG -department)
A	1985	Yes	Balanced	14	84	4440
B	2010	Yes	Balanced	6	36	1710
C	1998	Yes	Balanced	2	64	2780
D	2004	Yes	Balanced	9	72	2115
E	1992	Yes	Mechanical exhaust, natural supply	4	80	2820
F	2008	Yes	Balanced	4	38	1360
G	1978	Yes	Balanced	15	90	3300

4.3.2.4 Design of the systematic approach

The scheme presented in Figure 4.3.1, resulted in a systematic approach to evaluate LTCFs, with the purpose to analyse the relation between the indoor air quality and the outbreaks of infectious diseases. This approach consists of two checklists and a semi-structured interview to evaluate the building. The defined parameters of the indoor air quality have been used to set up a measurement plan. For the comparison of the outbreaks in LTCFs, the history of infections is used, taking parameters from literature. The general health and comfort variables are incorporated in a questionnaire. In Figure 4.3.2, an overview of the evaluation instruments is illustrated. The systematic evaluation approach consists of four parts as illustrated in Figure 4.3.2. Each is described and explained below.

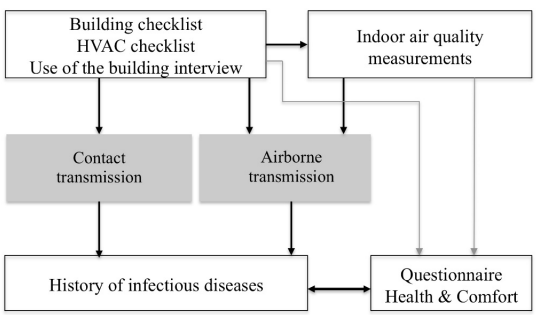

Figure 4.3.2. Scheme evaluation tools

4.3.2.5 Systematic approach

Building and HVAC evaluation

As illustrated in Figure 4.3.2, the evaluation of the building characteristics consists of three parts: the building characteristics (via checklist), the Heating Ventilation and Air Conditioning (HVAC) systems (via checklist) and the use of the buildings (via interview). Detailed information on the checklists and questionnaire is found in the (digital) supplementary material. The checklists on both building characteristics (for example addressing outdoor conditions, building structure and material use) and HVAC systems (for example addressing natural/mechanical ventilation, humidity management, contaminant source control and maintenance) have been composed to evaluate characteristics that were found in literature to play a role in the transmission of diseases. The checklist can be filled out at

the location of the building. The table in Appendix I indicates hypothesized connections of the building characteristics to the transmission routes and with that to spread of infectious diseases. Technical information from drawings and descriptions e.g. information about the indoor air supply and exhaust, design ventilation rates, floor plan and lay-out are needed for both checklists. Airflow measurements are also part of the checklist of the HVAC systems. A semi-structured interview, which takes around 30-60 minutes, with a team manager of the PG department, should provide for the desired information about the use of the building.

Indoor air measurements

The indoor air measurements assume temperature, relative humidity, and CO_2 concentration measurements are performed in a living room and two bedrooms per LTCFs. The position in the room is chosen taking into account the behaviour of the resident and in approval with their caregivers. The measurement period is set at one month, with a measurement interval of 10 minutes. An Eltek data logger with three sensors (GW47) were used to measure temperature (accuracy: ± 0.5˚C (5 to 40˚C), resolution: 0.1˚C), relative humidity (accuracy: ± 2% (10 to 90%), resolution: 0.1%), and CO_2 (accuracy: ± 50 ppm + 3% of measured value (0-5000 ppm) resolution: 1 ppm). Particulate matter measurements are performed during one day with an interval of one minute. These measurements were obtained using a Remote 2014 Airborne particle counter by Lighthouse; it counts particles with a size smaller than 10, 2.5, 0.7, and 0.5 µm. Outdoor conditions are obtained from nearby meteorological and environmental measurement sites.

Assessment size/frequency of the outbreaks of infections

To compare the frequency, size and duration of an outbreak of an infection, parameters are defined that describe the occurrence of infections over the past 5 years. This information needs to be requested at the LTCF. When the information is not available at the site information can be requested at the municipal health services from the corresponding region.

Comfort and health evaluation

The indoor air quality and the building characteristics also play an important role in comfort and health of the building occupants e.g. Wolkoff (2013). Therefore, a questionnaire has been set up to evaluate the perception of comfort and general health aspects of the health care professionals of the PG departments of LTCFs (HOPE, 2018). Detailed information on the health and comfort questionnaire is found in the (digital) supplementary material.

4.3.2.6 Analysis of data

Results of the building analyses

An overview of the results for all buildings is developed to provide insight in the current situation in the PG departments of LTCFs. First, the data type of all questions has been defined. Depending on the measurement level, the data is analysed. For ratio and interval data boxplots are made (Figure 4.3.3a). The minimum and the maximum of this boxplot are defined from the data of the investigated buildings. Boxplots are displayed horizontally, the least favourable condition at the left, and the most favourable condition at the right. This is done from the point of view of preventing the spread of airborne infectious diseases. The number of buildings that are included in this analysis is indicated at the right of the graph. From the variables with an ordinal measurement level, similar boxplots are made from the range of possible answers (multiple choice) and shown in (Figure 4.3.3b). The minimum value is the least favourable condition, and the maximum value is the most favourable condition. Horizontal bars, as shown in (Figure 4.33c), are used to show the results of the binominal and nominal data. The bars represent the percentage of the investigated buildings for which this answer is applicable. The data of the questionnaires of all locations (N=95) have been put together. The use of the buildings is measured on the basis of an interview. The answers were processed using a data sheet to order the information. This structure was used to compare the use of the buildings, similarities and differences are discussed for each of the categories: general, residential groups, activities, control over the indoor climate and about the protocol in case of an outbreak.

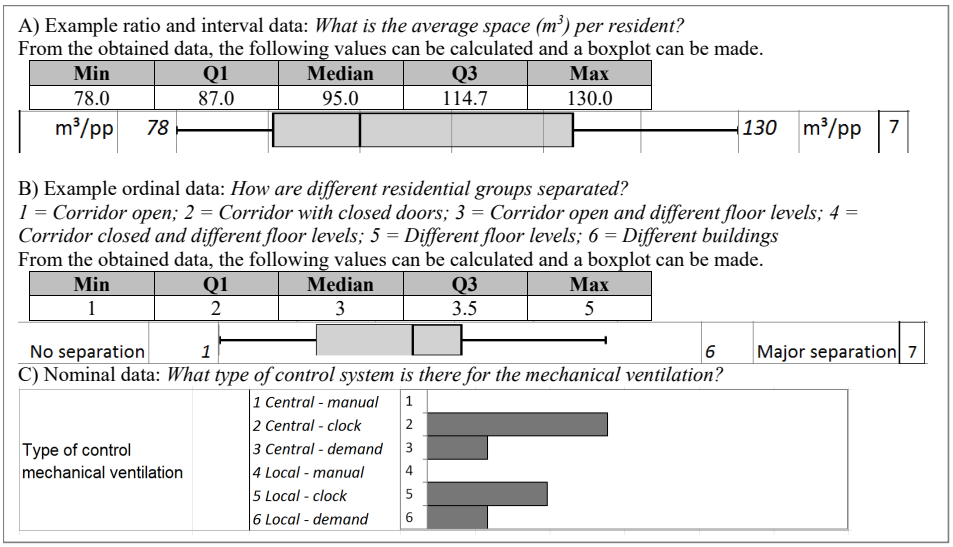

Figure 4.3.3: Examples boxplots and graph to give an overview of the results

Ranking buildings

For each building, the results of the evaluation are compared with the other investigated buildings. The score of a variable for one building is indicated with a grey bar in the boxplot Figure 4.3.4 bottom. This bar indicates the score of that building is in quadrant 4 of the boxplot. The buildings are ranked to the quadrant the score is Figure 4.3.4 top. This indicates how well the building scores compared to the other investigated buildings. The score does not imply that a building with a score of “1” is, in any case, good and a score of “4” is bad. Due to the lack of guidelines and reference no optimum can be defined yet. The ranking is used to find the effect of differences between buildings and its effect on health and comfort. This allows benchmarking of facilities on the specific issues monitored.

	1st quadrant	2nd quadrant	3rd quadrant	4th quadrant
Score	4	3	2	1
	Least 25%			Best 25%

Example: What is the average space (m^3) per resident? Answer building X: *125 m^3/pp.*

Within 4th quadrant so a score of 1 is assigned to this building for this variable (right side of graph)

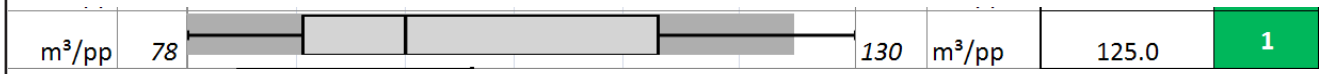

Figure 4.3.4; Schedule and an example of assigning scores to the buildings.

Comparing buildings

Radar plots are used to give a quick overview of all scores of the different LTCFs. Figure 4.3.5 shows examples of the radar chart for two of the investigated LTCFs. Radar charts for all seven LTCFs investigated are attached in Appendix II. The radar consists of three parts, (I) the building, HVAC characteristics and physical measurements, (II) the outbreaks of infectious diseases, and (III) comfort and health. Each category consists of different parameters represented at the axes of the chart. It gives a quick insight into which aspects the building scores good or bad and helps to find possible correlations between those three. Variables are assigned to the parameter that they influence. Each variable is used only once. If one of the variables, which are included in the score of one parameter at the axis, is unknown, the average of the other variables is used to determine the score. The percentage of answered questions is indicated for each axis. The scores range from 1 to 4 (Figure 4.3.4). The score from 1-4 is from the best 25% (score 1) of the investigated buildings till the worst 25% (score 4) of the rated buildings. The value "0" is assigned when a parameter could not be calculated because less than 75% of the answers are known. The percentage behind the parameters represents the amount of answered questions. A score of 5 indicates that the parameter does not meet the requirements of the building legislation.

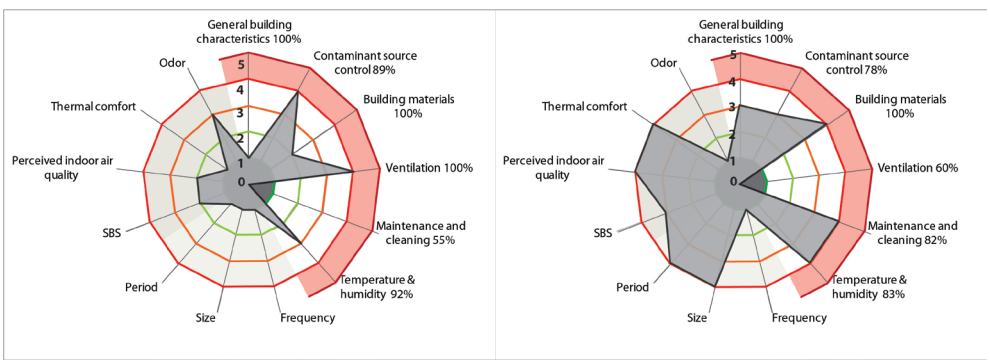

Figure 4.3.5; Radar chart for two of the investigated LTCF's.

The first part of the radar is composed using a selection of the building and indoor air related parameters and consists of six axes: (1) General building characteristics, (2) Contaminant source control, (3) Building materials, (4) Ventilation, (5) Maintenance and air cleaning, and (6) Temperature and humidity. Each axis consists of different variables. The list of variables connected to an axis is found in Appendix III. Because the contribution of each of these variables is unknown, no weighting factor has been applied. The second part of the radar indicates the scores of three parameters referring to the outbreaks of infections.

Perceived health and comfort scores are shown in the third part. Information from the personal questionnaires used for this ranking is provided in Appendix III. These are the results of the questionnaire for the investigated building. The chart should give a quick insight into the aspects for which a building has good or bad scores and helps to find possible correlations between the three categories.

Applying these radar charts, possible relations can be found and further analysed. By sorting the buildings, for example, on the frequency of infections, patterns in the building and HVAC characteristics might be observed. These possible relations can then be further analysed depending on the data.

Development of the design guidelines

Because there are many contributing factors, a large sample size is required to find correlations. Therefore, a methodology that can be applied in many LTCFs is necessary to find the important contributors to the transmission of airborne infections. By using the approach as a system to store information about the building and its indoor environment as well as a tool to find the relations among the building characteristics, indoor air quality and its effect on the transmission of infections, a large sample size can be achieved. When a sufficient large sample size is obtained, the information stored in the systematic approach can then be used as a basis to derive correlations and define specific design guidelines for LTCFs. The assessment procedure may be repeated for individual LTCFs at a predefined time interval to assure up-to-date performance over the life-time of the LTCF.

4.3.2.7 Testing the systematic approach

As described in the method section, the systematic approach was tested in seven LTCFs in the Netherlands. It was possible to execute the checklists, interviews, and observations, which needed to be done at the location of the LTCF, in one day. For some parameters it was not possible to obtain reliable information or no information was found at all. An interview of 30-60 minutes with a team manager of the PG department was planned to give insight in the use of the building, the general activities during the day and their locations. Indoor air measurements were placed for a time span of approximately 40 days. These measurements were only carried out at two locations due to the availability of measurement equipment. Information about the outbreaks of infections from the past 5 years was requested at the health care facilities participating in the research. However, it appeared that LTCFs only register this information during an outbreak. When the infection is over this information is not saved. From only one health care facility this information was directly accessible. Because health care facilities are mandatory to report when

someone suffers from a notifiable disease or when there is an unusual number of sick people with diarrhea, jaundice, skin diseases or other diseases of infectious nature (GGD, 2012), the municipal health services from the corresponding regions were contacted for the requested information. However, some municipal health services were not willing to give this information and the completeness of the obtained information differed. For filling out the questionnaire, a time period of two weeks was given, this resulted in a response from 7 to 21 participants per LTCF.

4.3.3 Discussion

4.3.3.1 Evaluation of the systematic approach

The aim of the systematic approach is to analyse if differences in building characteristics, HVAC systems, and use, influence the spread of airborne infectious diseases. Therefore, data from a significant number of buildings, with a variety of characteristics, is required to obtain enough power to determine the role of the indoor air in the transmission of airborne infections. This current approach is intended to structure this information. Additionally, it should give an overview of the current buildings and rank these; the structure should facilitate a comparison between buildings. The advantage of using this tool is that successful interventions in one building can be addressed and this knowledge can be used and applied in other buildings. Because this systematic approach is also used to store the information about the buildings, it is dynamic. New buildings, renovations, and new technologies will keep it up to date and should raise the quality of the desired outcome of the performance indicators. Below is discussed whether the systematic approach succeeds in this objective and how it possibly can be improved.

Availability and reliability of the information

To perform the systematic approach at a LTCF, assistance is necessary from different employees, which need to be willing to participate and put time and effort into finding the required information that is not frequently used. This appeared to be a factor that makes it difficult to find facilities that want to collaborate in the research and to get all the desired information from the LTCF. A change in the management and control of the building related data is necessary to make the information better accessible and comparable. If this information would be stored systematically, for example using the developed technique, it will also provide useful information to the facility mangers: it will give them insight in the quality of the building and its effect on comfort and health. Preferably this would be done at all LTCFs so it can be used for comparison and as a benchmark for LTCFs.

The reliability of the obtained information depends on the knowledge of the people who provided the information and the availability of documentation. Information provided from the interview is based on the experience, knowledge, and interpretation of that person. Some health care organizations are not willing to give information about the history of infections because they doubt the comparability of the available information. Although infectious diseases have to be reported at the municipal health services, conform the Dutch Health Law Article 26 "Reporting institutions" (RIVM, 2008), there is no uniform structure on how this information is stored. The rules can be interpreted in various ways, the quality and consistency differ and therefore it is hard to compare the data. This is also confirmed by the municipal health services. The manner of registration by the LTCF is not prescribed by the government, neither is the method of registration of the municipal health services (RIVM, 2008). If we want to determine factors contributing to the spread of airborne infections, a systematical way of data collection is necessary, to rank and score the buildings on the parameters of the outbreaks of infectious diseases. A remark should be made that contamination does not always lead to an infection, but that an infected person is a source and carrier of the infection. Independently of this systematic approach, it is recommended that a more uniform system to structure this data is able to compare outbreaks in different LTCFs and to study whether interventions are effective. Currently, this specific information as available at LTCFs lacks consistency and agreement towards each other.

Contributions variables, weight factors and*/or hierarchy*

This approach of the building assessment has been developed from the point of infection prevention. So, the parameters and the scores have been defined to reduce transmission. Perceived health and comfort are also evaluated because these are affected by indoor air as well. However, favourable conditions for health and comfort are not necessarily the same.

The parameters at the axes of the radar charts consist of (a selection of the) different variables investigated. The impact of each of these variables is yet unknown. In the current analyses, the contribution of the different variables that have been defined, are divided into different categories in which their contribution is assumed to be the same. The average of the variables is used to calculate the score of one parameter. To give insight into the scores of the variables within one parameter, sub radars can be made of these scores. Based on these sub radars, it can be discussed whether the average, median, trimmed mean, modus etcetera is the best representatives for calculating the score of the parameters in the radar chart. The analyses of the sub radars and median versus average scores can be used to give more insight into how the hierarchy should be applied. When there are large differences

within the sub radars, hierarchy and weight factors probably will become more important.

More research is needed to find out whether weighting factors or a hierarchy should be applied in this analysis. This can, for example, be done using the Delphi method (Somerville, 2007), the "ranking type" Delphi (Okoli and Pawlowski, 2004) or the Analytic Hierarchy Process (Saaty, 2008). These methodologies are intended to structure the variables based on their importance in the contribution of the transmission of airborne infections. In this analysis, possible interactions should be taken into account as well.

Reliability / Contributing variables

From the parameters in the radar chart that are derived from more than one variable, at least 75% of the variables are necessary to calculate the parameter. When fewer variables are known the parameter gets a score of "0". This value is chosen because the scoring interval is 25%. The nominal variables cannot yet be incorporated in the radar chart. So, for example air movement, which is important according to the literature study, is not included in the scores. To include this variable, it needs a higher measurement level. This means that the air movement will have to be quantified or different types of air movements need to be defined, and arranged from least to most favourable type. For the contribution of the indoor air quality on the transmission of infections by weakening the defense mechanism of individuals, it is unfortunate that the perceived health is hard to evaluate for the residents. Methods that could be applied are an observational study and/or an interview with health care professionals on their experience about health, wellbeing and behaviour of the residents. However, these methods are time consuming.

In the current in-situ analyses the temperature, relative humidity, and CO2 concentration were only measured at two locations. These measurements, however, are integral parts of the building assessment and therefore should be performed in every building analysed. These measurements make the evaluation more performance based and support the validation of the model. Requirements can be added to the descriptive variables to ensure comparability. Currently, only maintenance, the year the building was built and renovations take the quality of the systems (for a small part) into account.

The starting point of the current model is the role of the building characteristics and the indoor air quality. There are certainly more factors that play a role in the prevention of outbreaks and the indoor air quality. Related to the prevention of outbreaks cleaning regime and frequency has to be considered as well as the compliance to the hygiene protocols by the professionals. The proposed approach could, of course, be extended with these parameters.

4.3.3.2 Further development

To fulfill the objective of the systematic approach adjustments are required. The Design Research Methodology (DRM) can be used to structure this development (Blessing, 2004). In addition, the sample size of the participating LTCFs should be enlarged. Most preferable would be to include buildings on the basis of the number of outbreaks, to ensure variance. However, as previously described, it is not possible to obtain this information. When the model has been validated, relations between on one hand the building characteristics and HVAC systems, and the other hand the spread of infectious diseases and health and comfort of health care professionals can be analyzed. When more information is available about the desired conditions and the effect of the building and HVAC characteristics, design criteria for the buildings can be established and integrated in the model. Finally, it can be applied in all LTCFs to structure the building and HVAC characteristics to define their positions compared to others. This should result in defining effective interventions or design guidelines to improve the indoor air quality and reduce the number or size of outbreaks of infectious diseases.

There are still some aspects that limit the applicability of this approach. First of all, a more unambiguous and structural way to collect data about the history of infectious diseases is needed. Information about the HVAC systems is sometimes hard to find, because data is not stored. This issue confirms the relevance for a systematic approach to store such information. Also, indoor air measurements need to be performed at more buildings to obtain better insight in the indoor air quality. The evaluation technique itself needs to include the nominal variables in the scores. Application of weight factors and hierarchy is required but need further research. This is supported by an increased sample size.

4.3.4 Conclusion

This research was performed to provide a systematic approach to develop design guidelines for the indoor climate in LTCFs in relation to spread of infectious diseases. An evaluation tool has been designed to evaluate building characteristics, HVAC systems, indoor air quality, the outbreaks of infectious diseases and health and comfort in LTCFs. Only little information and guidelines are available about the favorable indoor environmental conditions in LTCFs and not much is known about the current indoor air quality. Therefore, the developed systematic approach does not define criteria yet but it ranks, compares the buildings, and gives an overview of a sample of buildings.

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Chapter 5

Decision-making on strategic values

Based on the following paper:

Huisman, E.R.C.M., Appel-Meulenbroek, H.A.J.A., Kort, H.S.M. and Arentze, T.A. "Identifying benefits of nursing home real estate through a laddering technique", *Submitted.*

Abstract

Purpose Board members and real estate managers (decision makers) play an important role in the decision-making process in nursing home organisations. Therefore, the aim of this study is to get in-depth knowledge about the underlying motives that drive these decision-makers and which benefits they want to achieve for the nursing home real estate.

Design/Methodology The laddering technique was used to interview seven decision-makers divided over seven organisations in the Netherlands. These generated the individual requirements, the considerations of the decision alternatives, the relevant context attributes and their mutual relationships.

Findings This study provided detailed motivations behind real estate decisions for nursing home organisations. The findings showed that decision-makers strive for an attractive and inspiring environment. Therefore, besides financial aspects the values increase satisfaction, quality of life and participation were highly appreciated benefits. These values are connected to goals of well-being and innovations in healthcare. Functionality, flexibility, and technology were important attributes to achieve the ambitions of the nursing home organisation.

Practical implications The insights can support decision-makers in healthcare facilities with adding strategic value to the organisation with their real estate. Understanding how to obtain certain benefits from nursing home real estate may result in a better fit between real estate, organisational objectives and user needs.

Originality/value This study opened the black box of the decision-making process in a nursing home context. Also, the laddering technique is used as a new method to explore real estate related decision-making processes of nursing home managers more in-depth.

Keywords

Corporate Real Estate Management, Added value, Laddering, Decision Making

5.1 Introduction

In the field of organization theory and strategic management, strategic decision making is a topic of great interest (O'Brien, 2011; Ahmed and Bwisa, 2014), but also in the field of CREM (Heywood and Arkesteijn, 2017). The results of decisions made during the design process are the characteristics of the building that the organisation needs to work in and which are related to strategic choices. Which building characteristics or organisational values should be prioritized, depends on the ambitions of the organisation, the level of importance that various user groups attach to positive and negative effects of design alternatives, constraints such as time, money, and legislation, and the external context (van der Voordt, 2016). However, the prioritizing of building characteristics and organizational values also depends on the decision-makers. The perceived added value of a particular design choice over other options or managerial interventions in a building-in-use can be very diverse due to the opinion and expectations of decision-makers (van der Voordt, 2016).

Nursing homes organisations strive to be an organisation that focuses on the care and the functionalities of the indoor environment (like e.g. healing environment) in order to improve the quality of life of the residents and the well-being of the employees. For example, studies showed (e.g. Ulrich *et al.,* 2008) that the design of healthcare environments could achieve improvements such as reduction in medication errors, patient falls and stress levels. In addition, good design also increases patient's satisfaction with care and can contribute to the development of patient-centered care. Thus, decisions concerning healthcare buildings are important because they affect people and work processes for many years (Elf *et al.,* 2015). Therefore it becomes more important to develop a deeper understanding of the management and design of real estate by nursing home organisations. It is important to identify how their real estate managers make their decisions when considering to design new healthcare buildings or renovating existing healthcare buildings to accommodate the changing context in the care sector.

To make a decision it is necessary to know the problem, the need and purpose of the decision, the criteria of the decision, their sub criteria, affected stakeholders and alternative actions (Saaty, 2008; van der Voordt *et al.,* 2016). Gathering such information is necessary to understand the context and problem better, as input for considerations to make decisions about the problem. Decision making illustrates the thinking process that is used towards making better choices. It involves many criteria and sub criteria which are used to rank the alternatives of a decision (Saaty, 2008). There are many different CRE alignment models available in the literature (Arkesteijn *et al.,* 2017) with their own strategic point of view on how to make decisions. However, it is not clear which key values are incorporated in the design and management of nursing home real estate and how the concept of added value is

adopted in daily practice (van der Voordt, 2016). In addition, the way in which real estate alignment decisions are made still stays a black box (Arkesteijn *et al.,* 2017). Therefore, the purpose of this paper is to get insight in the decision-making process and underlying motives of real estate managers managing nursing home real estate portfolios towards obtaining specific strategic benefits in the changed context. The laddering technique is introduced in the field of CREM to identify the variations in mental representations of decision-makers to investigate the differences in real estate choices. Laddering is a technique of qualitative research in understanding behaviours. It has been utilized in different fields (e.g. marketing) in order to explore individuals' opinions, attitudes and beliefs but not yet in CRE (Veludo-de-Oliveira *et al.,* 2006).

5.2 Theoretical background

The design of nursing homes is an important quality factor in healthcare nowadays. Nursing home organisations integrate healthcare architecture into its strategic plans to improve the quality of care they offer (Elf *et al.,* 2015). The most important strategic alignment decisions in the planning and design process are made in the early phases (Elf *et al.,* 2015). The initial phase is a conceptual phase in which user groups meet to discuss ideas and requirements and prepare for design decisions (Huisman *et al.,* 2018). New innovative care models, such as healing environment, and various perspectives can also be integrated in the design during this phase. The primary purpose of the initial phase is to define the nursing home environment from the user's perspective and align this perspective with the strategic plan of the nursing home organisation. A more comprehensive understanding of the alignment process would be important for decisions for the long-term planning of future options for health care real estate (i.e. new build, renovation, and maintenance). Such decisions are related to the changing context in the care sector, driven by the aging population and the introduction of new technologies and concepts (Rodriguez and Thomson, 2018). Decisions about e.g site selection and building design are critical to react quickly to these changes. The next sections therefore discuss existing theory on decision-making processes and achieving CRE alignment during this initial phase.

5.2.1 Corporate real estate alignment

Attention to the strategic role of real estate management is growing and decision-makers recognise facilities as a strategic resource (Rodriguez and Thomson, 2018). CREM aims to find the best possible match between demand and supply. This best possible match is influenced by the appreciation, preferences, and interests of the stakeholders on the one hand and the possibility of changing the real estate supply on the other hand (van der Zwart, 2014). The decision making process of CREM is complex because of the various s takeholders. Gibler and Lindholm (2012) state that if organisations want CRE resources to add value to the organisation, they must align corporate real estate strategies and decisions with core business strategies. However, the relationship between CRE and organisational strategy in order to deliver organisational value is still an issue for CREM (Heywood and Arkesteijn, 2017). Generating this added value is a challenge as decision-makers indicate that it is difficult to achieve alignment (Heywood, 2011).

Over the years, several models have been developed to align corporate real estate strategies and decisions with core business strategies. However, after comparing many of them Heywood and Arkesteijn (2017) conclude that the CRE alignment process is complex and it is not possible to show CRE alignment as a singular definitive thing. De Vries (2007) developed an input-throughput-output model to study the effects of real estate interventions on organisational performance. Input is defined as any information added to the system. Throughput is defined as those changes made to the input and output is the results of choices and interventions. Outputs can lead to different types of outcome or added value parameters of the core business.

There are different lists of strategic added values of real estate and real estate strategies available in the literature (Riratanphong and van der Voordt, 2015; van der Zwart, 2014). These values and strategies have been rephrased and new additional values were introduced. In the most recent study, Van der Voordt (2016) added care sector specific values such as sustainability and creating a healing environment. A healing environment is a place where the interaction between patient and staff produces positive health outcomes within the physical environment (Huisman *et al.,* 2012). Supporting innovation, increasing user satisfaction and improving the organisation's culture were already identified as highly appreciated values within the hospital environment by decision-makers (van der Zwart, 2011).

The added values of real estate and strategies can be realised through various CREM interventions. Van der Voordt *et al*. (2016) describe possible CREM interventions that may add value to an organisation. These are: Changing the physical environment (on different

scale levels: portfolio, building and space), Changing facilities services, changing the interface with core business, changing the supply chain, changing the internal processes and strategic advice and planning. Specific healthcare environmental interventions and their impact on patients' health outcomes are well studied in the last decade (Nazarian *et al.,* 2018). A growing body of literature showed the effect of the physical environment on the healing process and the well-being of patient, family and staff (Huisman *et al.,* 2012). So decisions about these interventions are important.

5.2.2 Decision making processes

Choice behaviour forms the basis for the decision making process about possible interventions. Choices could be impulsive decisions or become embedded in human behaviour which happens almost without any reflection process at the moment the choices are performed. On the other hand, there are conscious decisions for active choices which we think we are in control of (Horeni *et al.,* 2014). Craik (1943) postulated that the human mind constructs 'small-scale models' of reality that are used to anticipate events, to reason, and to provide explanation. Later, the concept of mental representations (MR) was explicitly introduced in Johnson-Laird's mental model theory (1983). MRs are the result of individual perception being stored in working memory each time a choice situation is being considered (Arentze *et al.,* 2008; Dellaert *et al.,* 2008). MRs will generally involve a simplification of reality including only relevant attributes of the decision alternatives, benefit requirements of the decision maker, situational variables and the causal relations between them (Arentze *et al.,* 2008; Dellaert *et al.,* 2008). The benefits describe the outcomes in terms of dimensions of more fundamental needs (Arentze *et al.,* 2008; Dellaert *et al.,* 2008). They conceptualize a person's need related to the decision such as a feeling of safety or pleasure (Arentze *et al.,* 2008; Horeni *et al.,* 2014). A situational variable is a concrete characteristics in the frame of choice which cannot be influenced by the acting person in the moment of decision making (e.g. location, legislation, concept etc.). A benefit can be influenced by several attributes at the same time.

Different methods exist to explore or elicit preferences of decision makers such as stated choice experiments. A stated choice experiment is a quantitative technique for eliciting individual preferences. It allows researchers to identify how individuals value selected attributes of a programme, product or service by asking them to state their choice over different hypothetical alternatives. However, a disadvantage of this technique is the limited possibility to ask more in-depth questions and that only a few main value drivers can be tested at the same time.

Therefore, the means-end approach (Reynolds and Gutmann, 1988) seems a more appropriate way to give insight in the MRs of nursing home-decision makers. It can be used to

uncover the underlying motives, consequences, and personal values that drive nursing home decision-maker's choices. It is based on a theory that product and service attributes are associated with consequences, or product benefits and risks, and even the personal values the product can help consumers fulfill (Veludo-de-Oliveira *et al.,* 2006).

Table 5.1 gives an overview of the possible decision alternatives, attribute and benefit variables from literature regarding CRE decisions and healing environments. Decision alternatives for a nursing home CREM intervention are the possibilities to design a new building on a new location or existing location, to renovate an existing building, to plan maintenance or to sell a building. The attributes are real estate decisions involving location, facilities, accessibility, building physics, interior design, flexibility, participation and technology. From the literature it is known that CRE can add value by selecting locations and facilities that attract customers and employees. For example, the choice for a good accessible location with an area of high quality of living for staff is a possible strategy (van der Zwart, 2011). Decisions related to building physics (e.g. light, acoustics, indoor air quality) may affect occupant's comfort, and their health and well-being, as well as their productivity and could influence employee's satisfaction (Lindholm *et al.,* 2006; van der Zwart, 2011). Interior design choices that fit the values of the organisation can be a real estate strategy to support the culture of the organisation. A flexible real estate strategy includes choosing spaces that can be adapted to multiple purposes and creating flexible workspaces within the structures of the building to support changing business processes (Lindholm *et al.,* 2006). Participation of stakeholders in planning and design of workplaces could result in spaces that create an inspiring atmosphere and understanding the values of the various stakeholders (Lindholm *et al.,* 2006; Huisman *et al.,* 2018). Last, the use of technology plays an important role in improving productivity by real estate (van der Zwart, 2011).

Benefits described the impact of the attributes on organisational performance. Regarding possible benefits, the healing environment concept as applied in hospitals, can be used as starting point to identify possible motives of nursing home decision-makers. The healing environment concept as the ultimate benefit sought, includes the perception of the environment, the interaction with the environment and the well-being of the users. Perception of the environment includes e.g. atmosphere and image (Ulrich *et al.,* 2008; Huisman *et al.,* 2012), while the interaction with the environment is related to e.g, safety, mobility, self-esteem and productivity (van der Zwart, 2011; Huisman *et al.,* 2012; Zhang *et al.,* 2019). The well-being of the users contains e.g. user satisfaction, improved quality of care and increase well-being of employees (Huisman *et al.,* 2012; Zhang *et al.,* 2019). Benefits of the environment for ageing adults has also been reported (Kort, 2017). Due to the changing context in the Dutch healthcare sector, reducing life cycle cost and total cost

has become more important (van der Zwart, 2011). For example, co-operation in construction is a strategy to reduce costs for healthcare organisations. In practice, possible other variables could come forward too when the decision making process is analysed in more detail.

Table 5.1: list of possible decision alternatives, attribute and benefit variables based on the theory of added value with real estate and the healing environment concept

Decision Alternatives	To build a new building on a new location; To build a new building on an existing location; to renovate an existing building; to plan maintenance of a building; and to sell a building.
Attribute variables	Location; Facilities; Accessibility; Building physics; Interior design; Flexibility; Participation; and Technology.
Benefit variables	Atmosphere; Image; Safety; Mobility; Self-esteem; Productivity; User satisfaction; Improve quality of life; Increase well-being of employees; Reduce of costs.

5.3 Methods

To explore which attributes and benefits drive nursing home decision makers in their choices the technique of laddering is introduced. Laddering refers to an in-depth, one-on-one interview technique used to develop an understanding of how people translate attributes of products into meaningful associations with respect to self (Gutman, 1982). Laddering involves a tailored interviewing format using primarily a series of directed probes, typified by the "why is that important to you?" question, with the express goal of determining sets of linkages between the key perceptual elements across the range of attributes (A) and benefits (B)(Reynolds and Gutman 1988). In the field of consumer behaviour, laddering is a successful means-end approach to investigate why and how consumers shop for example (Gutman 1982, Horeni *et al.,* 2014). It allowed for the detection of causal links with which shoppers mentally connect different benefits (B), such as convenience and pleasure, to shopping attributes (A) such as parking spaces, decoration and personal service. Arentze *et al.* (2008) developed a semi-structured interview protocol, the Causal Network Elicitation Theory (CNET) for measuring MRs of decision problems through laddering. This process involves generating an individual context specific MR, where the individual benefits requirements, the attributes of the decision alternatives, the relevant context attributes and their mutual relationships become visible. In this study that technique is used to get insight in why and how nursing home decision-makers make real estate related decisions and

choices about the physical environment.

5.3.1 Participants

In 2018 13 board members or real estate managers of nursing home organisations were contacted and invited via email. Seven agreed to be interviewed within three months. Three declined because they did not work for the organisation anymore and three did not respond. The 7 participants were interviewed face-to-face through using CNET. The participants were selected based on their function as board member, real estate manager or facility manager in a nursing home organisation. All of the interviewed participants were men. In total, the participants were responsible for the real estate of 126 locations divided over 7 organisations. All interviews were conducted in private rooms of the participant's workplace and had a duration between 55 and 67 minutes. All interviews were conducted by the first author and audio-recorded with the permission of the respondents and transcribed verbatim.

Table 5.2: characteristics of the interviewed respondents

Respondents	Function	Responsible for number (N) of location(s)
1	Real Estate Manager	18
2	Real Estate Manager	18
3	Board member	13
4	Director	35
5	Real Estate Manager	23
6	Facility Manager	1
7	Real Estate Manager	18
		Total = 126

5.3.3 Procedure

Participants were presented with the hypothetical real estate decision alternatives in three steps. The first step was to consider the decision alternatives (a new building on a new location, a new building on an existing location, to renovate a building, maintenance of a building or to sell a building) by an open question asking: *Which decision alternatives are taken into account during real estate decisions of the nursing home organisation?* The second step was to determine the MRs. In this step the interviewer probed through open-ended questions which attributes and benefits the respondent considers relevant for making a choice for a decision alternative. The following question was posed to the respondents: *What are your considerations when you make a choice between these decision*

alternatives? The interviewer tried to identify the attributes and then proceeded with the question: *Why is this consideration important for the decision?* to identify the benefit. The interviewer used the predefined list of attributes and benefits (see Table 1), to identify variables mentioned by the respondents. However, there was room to add new attributes and benefits during the interview as well.

The interviewer used 'cards' and 'post-its' to construct the MR during the interview (see Figure 5.1). The values spontaneously mentioned in the second step could be indicators of the respondents' awareness of possibilities to add value with real estate. As this point, the structure of the MR was known and the purpose of the third step was to summarize the attributes and benefits variables in the MR. The interviewer went through the decision alternatives, attributes, and benefit variables in the model one by one. If the respondent was not satisfied with the summary, because a variable was missing or an incoming link between attributes and benefits appeared, the interviewer returned to step 2 to revise the MR.

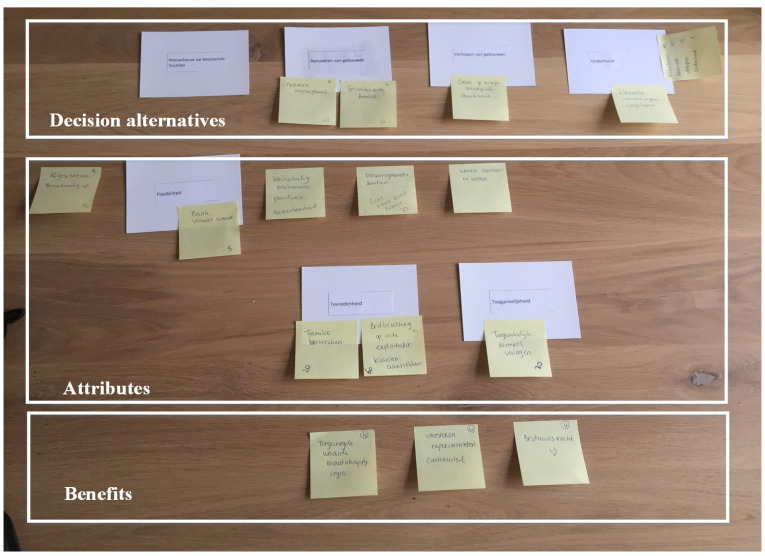

Figure 5.1: Example of a MR construction. The top layer represents the decision alternatives, the second and third layer represents the attributes and the bottom layer the benefits.

5.3.4 Validation of the analysis

Based on Gengler and Reynolds (1995) a content analysis was conducted to validate the constructed MRs collected during the interviews. The first step was a data reduction into separated phrases and a distinction made between attributes (A), benefits (B), and situational variables (S). Separated identifiers with similar meaning were grouped in broader codes. Last, the relation between the codes was determined and a visualisation of the decision-making process about the nursing home real estate decisions was made. The individual MRs were combined into one generic MR. The interviews were anonymised and data were analysed in MaxQDA 2018.

5.4 Results

The research findings are presented in two steps. First, an overview is given of the developed codes in the three categories and their mutual relationships. Secondly, diagrams are developed to simulate the decision-making processes for the five decision alternatives and the underlying attributes (A), situational variables (S) and benefits (B).

5.4.1 Developing the codes and their relations

Table 5.3 shows the content analysis results for nursing home real estate decisions by the respondents. In total 20 codes were identified. Each code is identified as an attribute (N=8), a benefit (N=8) or a situational variable (N=4). The attributes give an overview which physical conditions of the real estate portfolio were mentioned by the respondents. The benefits give an overview which organisational values the nursing home-decision maker hope to achieve with the real estate decision. Sustainability (A3), functionality (A4), stakeholders (A6) and building aspects (A7) were added as new attributes to the previously determined list in table 1. The attributes interior and building physics and services are integrated in the term building aspects (A7). The term building aspects (A7) also includes floorplan. The term accessibility (B6) is moved to the benefits column. Location (S1) was moved from the attributes column to the situational variables column. Reduce costs is renamed with the broader term finance (B3). The terms productivity, mobility, self-esteem and atmosphere were not mentioned as benefits in the summary. Freedom of choices (B2) and Social support (B8) were added as new terms to the benefits column. Quality of life (B4) is a broader term for the benefits improve quality of care and increase well-being of employees (table 1). User satisfaction is renamed in the term satisfaction (B5). The following four situational variables were mentioned: location (S1), lifecycle end (S2), concept (S3), and legislation (S4).

Table 5.3: Summary content codes for nursing home real estate decisions. Added codes retrieved from the interviews are given in bold and italic.

Code	Decision alternatives	Code	Attributes	Code	Benefits	Code	Situational variables
A	New building, new location	A1	Technology	B1	Safety	***S1***	***Location***
B	New building, exist location	A2	Flexibility	***B2***	***Freedom of choices***	S2	Lifecycle (end)
C	Renovation	***A3***	***Sustainability***	B3	Finance	S3	Concept
D	Maintenance	***A4***	***Functionality***	***B4***	***Quality of life***	S4	Legislation
E	Selling a building	A5	Facilities	B5	Satisfaction		
		A6	***Stakeholders***	B6	Accessibility		
		A7	***Building aspects***	B7	Image		
		A8	Participation	***B8***	***Social support***		

Table 5.4 gives an overview of the outcomes of each respondent. This table gives insight in the relations between the various codes and generic trends resulting from the interviews. A new building on an existing location (B) and renovation (C) were related most often to the attributes. This shows that these two decision alternatives got more attention by the respondents in this study. Mainly the attribute building aspects (A7) specifically focusses on the decision variables renovation (C), maintenance (D) and selling a building (E). The new attribute stakeholders (A6) includes cooperation and participation in planning and design and differs from the attribute participation (A8). The attribute participation includes participation of residents in their daily routine. Also, there is a variety in the number of benefits. The benefits safety (B1), freedom of choices (B2) and satisfaction (B6) were mentioned most often by the respondents. The situational variable location (S1) occurs in all decision alternatives. While the situational variable concept (S3) is not directly considered for a specific decision alternative. In the next sections, two examples of the decision making process will be further explained via simulation MR diagrams.

Table 5.4: Overview of the outcomes of the respondents (N=7). The relation between the decision alternatives, the attributes, situational variables and benefits. The framed cells identify generic trends retrieved from the interviews.

			Attributes							Situational variables			
		code	A 1	A 2	A 3	A 4	A 5	A 6	A 7	S 1	S 2	S 3	S 4
			Technology	Flexibility	Sustainability	Functionality	Facilities	Stakeholders	Building	Location	Lifecycle (end)	Concept	Legislation
Decision alternatives	New building, New location	A			1		1			2			
	New building, Exist location	B	2	2	1	1	**4**	**4**		**4**	1		
	Renovation	C		2	1	**5**	2	1	**3**	**4**			1
	Maintenance	D							4	1			
	Selling a building	E		1			2		**3**	**3**	1		
Attributes	Participation	A8					2						
Benefits	Safety	B1	2						**3**			1	
	Freedom of choices	B2	**3**				1						
	Finance	B3		1	1	1			1	1	1	1	
	Quality of life	B4					1	1				2	
	Satisfaction	B5						2				**3**	
	Accessibility	B6				1							
	Image	B7				1						1	
	Social support	B8						1					
Situational variables	Location	S1					2	1					
	Lifecycle (end)	S2				1							
	Concept	S3						2					
	Legislation	S4											

5.4.2 Insight in the decision-making process of nursing home real estate

The decision variables new building on an existing location (B) and renovation (C) were mentioned by most of the respondents when thinking about nursing home real estate decisions (Table 5.4). Therefore, the MRs of the decision-making process of these two decision alternatives are explained in more detail. For these two alternatives a diagram was constructed which visualises the decision-making process and the underlying motives of the respondents (see Figure 5.2 and 5.3). The other three decision variables are explained without a diagram. The top layer in the figures are the situational variables, the second layer the decision alternative, the third and fourth layer the attributes and the bottom layer the benefits.

5.4.3 New building on an existing location

The location (S1) and the end of the building life cycle (S2) were mentioned by the nursing home decision makers as important strategic factors before making a decision for a new building on an existing location. Furthermore, the location is important for the cooperation with other stakeholders (A6) in the neighbourhood (e.g. general practitioners, care organisations, etc.). In addition, the facilities (A5) in the neighbourhood nearby the nursing home location could also be a consideration to build a new building on the existing location. Facilities in the building like a restaurant or a swimming pool and facilities outside the building like shops or supermarket available in the neighbourhood were important for the participation (A8) of the residents. For example, the swimming pool. Not only the residents of the nursing home can use the swimming pool but also the swimming pool can be used for swimming lessons for children. For the residents there is a possibility to watch the swimming lessons of the children and this creates activities for the residents. When the residents have the possibility to participate in the daily routine it helps them to stay more active and reduce loneliness. Furthermore, it gives the residents more freedom in choices (B2). This all can increase the quality of life (B4) of the residents.

In consideration with the end of a building's life cycle (S2) functionality (A4) was mentioned to build a new building. This means that the functionality of the building does not align with the current values and requirements of the nursing home organisation and renovating the building towards current standards is too costly (B3). Technology (A1) is also mentioned as requirement for the design of a new building. In a new building it is easier to implement new technologies or innovations. New technology (e.g. e-Health systems or smart homes' systems) could contribute to improve the safety (B1) of the residents and staff in nursing home organisations. It also gives the residents the possibility

to make their own choices (B2). For example, to schedule the agenda for activities or in which part of the building you are allowed to be.

A respondent gave the argument that flexibility (A2) is a requirement of financial institutions in relation to the marketability of the building. It is necessary to get funding (B3) for the investments in the real estate portfolio of nursing home organisations. Flexibility means in this context flexibility in design, the building is future proof, and a combinations of functions are possible. In the design of a new building the real estate managers will achieve their sustainable ambitions (A3)(e.g. energy savings) with the aim to reduce costs (B3).

Some of the nursing home decision makers take time to involve stakeholders in the entire design process of a new building (A6) (e.g. employees, client boards, etc.) and ask them to reflect on the design decisions. When there is the possibility for stakeholders to participate in design decisions for the new building it will results in higher client and employee satisfaction (B5). Furthermore, it could improve the quality of life (B4) because the building better fits to the needs of the users.

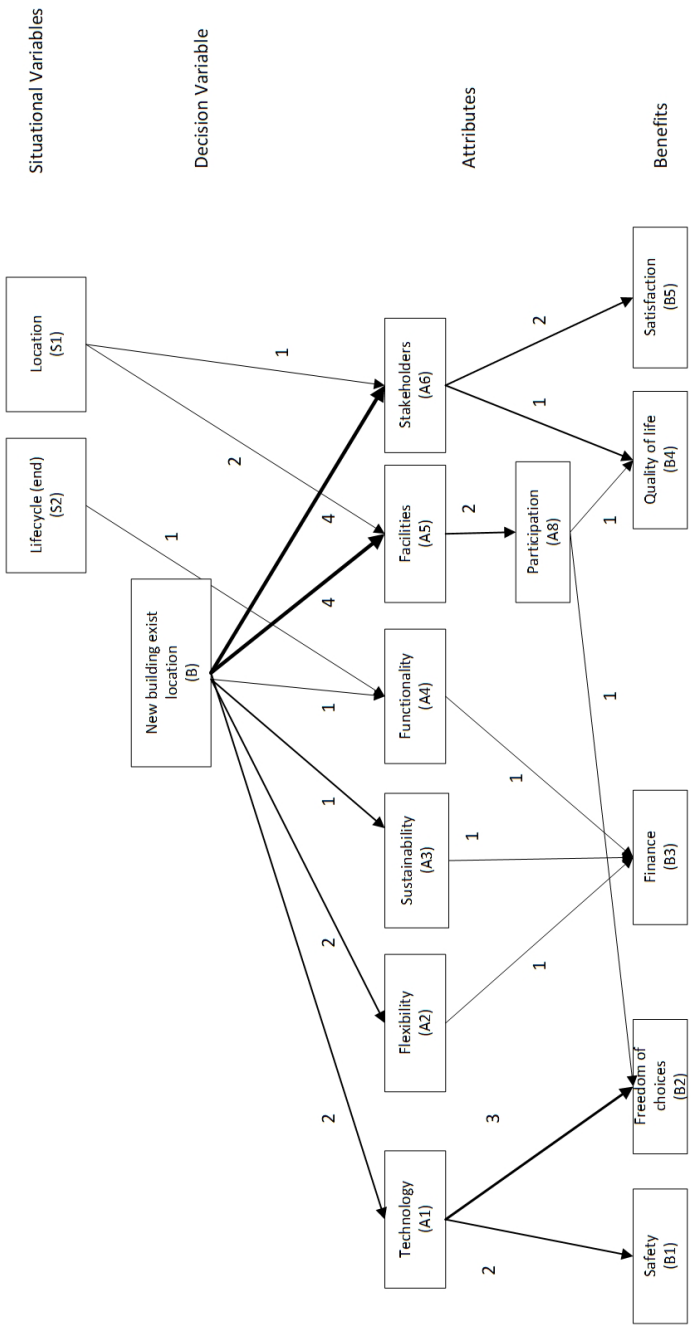

Figure 5.2: Simulation of the decision-making process for new buildings on existing locations by nursing home decision-makers and the relation between the situational variables, decision alternatives, attributes and benefits.

5.4.4 Renovation of a building

The location (S1) and legislation (S4) were mentioned as situational variables that influence the decision for renovation of a building in the real estate portfolio. In the current situation, the legislation has changed and this has consequences for the building requirements to deliver care. Often a renovation is needed to reach the higher standards to deliver care to the residents. This all starts with the building aspects (A7) (e.g. building physics, interior, etc). For example, to enhance the safety (B1) of buildings was mentioned as important benefit of the building aspects (A7). A distinction in safety can be made between fire security and social safety. Social safety means for example privacy and the accessibility of a building by visitors. To increase the fire security of a building, improvement of the lay-out of the floor plan and the use of fire resistant materials (A7) can contribute to this goal. A renovation of a building is a possibility to make new decisions and implement new possibilities regarding sustainability (A3) (e.g. energy savings via other light systems). This helps the nursing home organisation to reduce costs on the building exploitation (B3). Flexibility (A2) in the building has to deal with the possibilities of the building. Is the building flexible enough to transform to other functions or to add new functions in the building with the aim to increase the marketability (B3) of the building. Furthermore, how to optimise the use of square meters of the building. This all to keep a healthy exploitation or reduce total occupancy costs per bed (B3). In line with flexibility, functionality was mentioned. Functionality (A4) has a contribution to how well the building supports the primary 'core business' of the nursing home organisation. For example, how accessible (B6) is the building for the residents, their families and visitors. If the nursing home organisation will improve its image (B7), to enhance the functionality of the building is one of the considerations to realise this benefit. To facilitate (A5) a restaurant, shop or activity room in a building stimulate the residents to participate (A8) in the social environment. The facilities in the neighbourhood stimulate the residents to go out for shopping and this activity stimulates participation (A8) of the residents in daily life. Both examples give the residents the possibility to make their own choices (B2). For example, do I like to eat in the restaurant today or do I prefer to have dinner in the common living room. The last attribute is stakeholders (A6). To involve various stakeholders (A6) in the renovation process, the nursing home organisation creates social support (B8) but also it could increase satisfaction (B5) of the residents and employees. In addition, to encourage involvement of the stakeholders could contribute to the quality of life (B4) as well because the building better fits to the needs of the residents and employees.

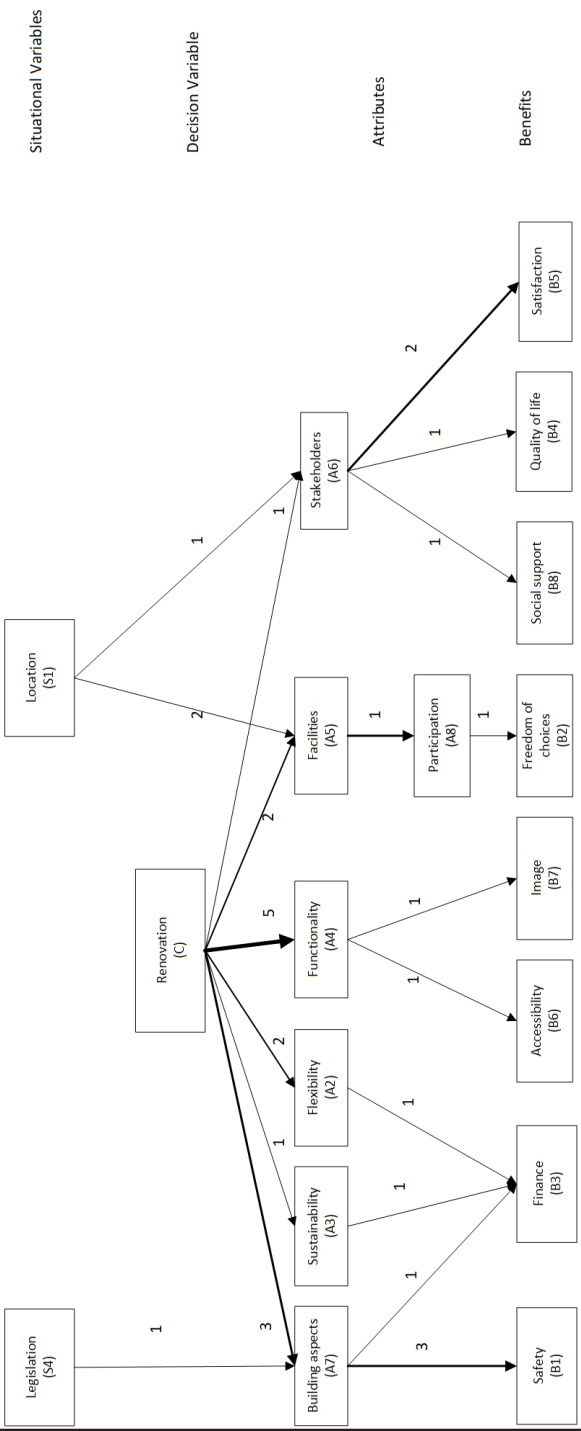

Figure 5.3: Simulation of the decision-making process to renovate buildings by nursing home decision-makers and the relation between the situational variables, decision alternatives, attributes and benefits.

.5.4.5 New building on a new location

A new building on a new location (A) was not highly prioritized by the respondents because this depends on the market position and the availability of new places to build. It is depended on the situational variable location (S1) and is a strategic consideration.

5.4.6 Maintenance

Maintenance (D) was mentioned to keep the building(s) in good condition and has more effect on operational level decisions.

5.4.7 Selling a building

To sell a building (E) was related to the end of the building lifecycle (S2). For example, the building aspects are not in line with the current requirements and legislation of the nursing home organisations. Furthermore, it depends on the current conditions of the building aspects. For example, how well is the fire safety of the building and is it still possible to guarantee the safety that we prefer as nursing home organisation. If not, it could be an argument to sell a building.

5.5 Discussion

In this study, the laddering technique was used to find benefits sought during strategic nursing home real estate decision making processes. The aim was to identify the various aspects of the decision-making process in nursing home real estate decisions and their mutual relationships. Understanding these aspects creates the possibility to obtain a better understanding of the benefits of design decisions for the primary process of care giving. The method used in this study contributed to obtaining more insight in the underlying motives and values of the decision-makers. The results contribute to a better understanding of adding values by nursing home real estate and the values mentioned in the literature. In the following sections, implications for theory, implications for practice, future studies, and limitations are discussed.

5.5.1 Implications for theory

Whereas the existing CRE alignment models focussed on the strategic level and describe decisions in an abstract way, this study contributed by describing the underlying motives and values for nursing home real estate decisions to make the added value with real estate more explicit. Another innovative aspect of this study is the use of the laddering technique to give a clear insight in the underlying motives and values that drive nursing home

decision-makers and the benefits they seek for their nursing home real estate. The formulated attributes give input for the design and the output is the benefit for CREM. For example, stakeholders as attribute is a supportive attribute for the core-business of the organisation.

Van der Zwart (2011) found that supporting innovation, increasing user satisfaction and improving the organisation's culture were highly appreciated added values by hospital decision-makers. In this study, similar results were found for nursing homes because the values increase satisfaction, enhance quality of life were highly appreciated benefits by nursing home decision-makers. These values are connected to well-being and concepts like 'healing environment' and 'planetree' (van der Zwart, 2011; Huisman *et al.,* 2012). Thus findings in this study showed that nursing home decision-makers strive for an attractive and inspiring environment as well. Moreover, they strive to involve their stakeholders in the design and decision-making process. To involve relevant stakeholders in the design and decision process gives nursing home decision-makers more possibilities to evaluate the real estate decisions and how to adopt the values in daily practice (Kang *et al.,* 2015).

In the theory of added value of CRE a distinction was made between exchange and use value. Where exchange value focusses on reducing costs or increasing values of assets, use value focusses on e.g. user satisfaction (Appel-Meulenbroek and Haynes, 2014). The simulated diagrams in this study show that the emphasis is on adding use value by the nursing home decision-makers. Specific for this sector, quality of life, safety, and freedom of choices are important use values. However, productivity was not mentioned as a benefit while this is one of the most sought after satisfaction added values in the literature (van der Voordt, 2016). Also, the benefits self-esteem, mobility and atmosphere were not mentioned as benefits while the impact of the building and the building related facilities on residents and staff is important for nursing home organisations.

Last, this study focused on the CREM intervention changing the physical environment. The results showed that the situational variable concept (S3) was as an important consideration for real estate decisions to reach the goals of the core business strategy, but was not related to an attribute. Thus, building concept may better fit to the CREM intervention changing the internal processes and strategic advice and planning and seen as a starting point for real estate decisions.

5.5.2 Implications for practice

This study contributes to the understanding and discussion of the complexity of healthcare real estate decisions. Understanding the changing context in the legislation and the quick development of new technologies and concepts in the care sector helps CRE managers to

react during early phases in the planning and design process. Furthermore, this study contributes to starting a dialogue between strategic real estate management and organisational management and which key values are currently incorporated in the design and management of nursing home real estate. The laddering technique used in this study is valuable to facilitate nursing home decision-makers to make their own decision-making process visible. In addition, it provide more detailed information on the decision-making process of their real estate decisions.

The decision-making processes in real estate decisions were very complex due to the variety of factors where a nursing home decision-maker has to deal with. The specific chains of the MRs in this study are applicable for nursing home decision-makers to apply these in their own context. It helps them to formulate their own vision about their real estate strategy and corporate strategy and share this vision with other stakeholders.

5.5.3 Limitations/ Future studies

With this paper a first step is made in describing the underlying motives and real estate decisions from the perspective of nursing home decision-makers. The research design could be enhanced by including cases at the initiation phase, in order to make the underlying motives more specific for the nursing home sector. Further research is also needed, to improve understanding of how the concept of strategic values by real estate appeals to different stakeholders and to establish the perceptions of real estate added value from the perspective of other project participants or users. The aim of this study was explorative and there was saturation visible after five interviews. However, it would be interesting to test the results in a broader selection and to further develop the laddering technique for the field of CREM. It can be further developed for the other CREM interventions and more specified for the CREM intervention, changing the physical environment.

The literature suggests that measurement of the outcomes (e.g. Key Performance Indicators) is still underdeveloped and how the performance information is used in the decision-making process. Further research is needed to identify the Key Performance Indicators on which nursing home decision-makers want to steer and how to implement the Key Performance Indicators in the organisation. Various respondents mentioned Total Occupancy Costs per bed as important benefit to reach the organisation's goals. Additional research is needed to investigate the available knowledge on the alignment process on the real estate department of nursing homes.

5.6 Conclusion

This study described the underlying motives and benefits of nursing home decision-makers regarding the real estate. The present study contributes to a better understanding of the nursing home decision-making process of real estate. It shows that for nursing home decision-makers the emphasis lies on use values. Functionality, flexibility and technology were also important attributes to achieve the ambitions of the nursing home organisations. Furthermore, this study contributes to the operationalisation of the strategic values of nursing home real estate and getting more insight in their alignment process.

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Chapter 6

General Discussion

6.1 Introduction

The last decade a growing field of research has contributed to an improvement of understanding the added value of both corporate and public real estate and, furthermore, how to manage real estate while taking into account the needs as well as the interests of different user groups. Attention is growing towards building design as how to create healthcare environments which promote the well-being for the variety of user groups and their complex demands. This is based on the healing environment concept and the need for evidence-based design. Evidence-based design has been introduced in the planning and design of nursing homes to inform and guide decision-makers in which design factors are successful (Elf, et al. 2015). Relevant factors for decision-making in nursing homes organisations include: (i) shared decision-making, (ii) focus on outcomes based on the integration of evidence and experiences, and (iii) evaluation of healthcare environments (Elf, et al. 2015). Therefore, the aim of this research was "t*o gain a better understanding of the decision-making process of an accommodation strategy for nursing home organisations with a user-oriented focus and a bottom-up approach. This in order to contribute to support healthcare professionals in their work environment and to create an indoor environment suitable for frail older people's needs and desires"*. To achieve this aim, the following research questions have been addressed:

- What is the influence of physical environment factors on users of healthcare facilities?
- How can multiple user groups be successfully involved in the design decision-making process of healthcare facilities?
- How to create an indoor environment for multiple user groups (older people and healthcare professionals)?
- What are the underlying motives and values that drives decision-makers for the healthcare real estate they manage?

The literature on the relationship between the built environment and health outcomes and quality of care is expanding rapidly since 2011 when this research has started **(Chapter 2).** The literature has been searched again on the healing environment concept in June 2019 to identify articles published after November 2011 that addressed how the built environment affects healthcare building users' well-being and health outcomes. The same method as in chapter 2 was used. Furthermore, the search was extended to long-term care facilities design and construction. A cross-reference method was used for relevant literature retrieved from citations of the study described in **Chapter 2**. It resulted in six literature reviews and two studies on the relationship between the quality of the built environment and the quality of life of people with dementia (Eijkelenboom and Bluyssen, 2019; Zhang, *et al.,* 2019;

Joseph *et al*., 2016; Fleming *et al.,* 2016; Marquardt *et al*., 2014; Salonen *et al.,* 2013; Garre-Olmo *et al.,* 2012;). These studies will be discussed in this chapter, as a reflection on the key findings. In addition, implications for theory and practice and future research directions are provided.

6.2 Key findings

To identify appropriate interventions to add user-specific value to healthcare organisations, a literature review on the effects of the physical environment on the healing process and well-being of patients, family and staff was performed **(Chapter 2**). An important finding of this review is that the studies were primarily conducted in hospital environments (e.g. Ulrich *et al.,* 2004; Daykin and Byrne, 2006; Ulrich *et al.,* 2008). Studies including staff outcomes (e.g. satisfaction) were scarce and most outcomes were experienced based. Moreover, it has been noted that it is crucial to understand the needs and relationships between the various user groups and the integration of all these needs into the built environment of healthcare facilities. Therefore, based on the result of the literature search, this thesis has a user-oriented focus with an emphasis on staff for long-term care facilities. On top of this a focus is laid on the decision-making process for real estate strategies. The next step in the understanding of this decision-making process was the development of a structural approach for long-term care facilities (**Chapter 3**). This structural approach gives valuable information about whether basic principles actually meet the users' needs. Basic principles covered a list of requirements (based on the users' needs) regarding indoor environmental factors (e.g. light, acoustics, indoor air quality.) for the nursing home decision-makers. The concretising step supported nursing home decision-makers in addressing and prioritising which indoor environmental factors should be selected for modification or improvement. The evaluation step contributed to define objectives and conditions (Figure 1.2) as input for actualisation of the nursing home real estate strategy. Thus, the study fostered a better understanding of the steering mechanisms for nursing home decision-makers. It contributes the design decision making process by including the perspective of mutltiple user groups and how to add value with healthcare real estate.

It is known from previous studies that physical environmental factors such as light conditions, acoustical climate and the indoor air quality affect people (Zhang, *et al.,* 2019; Marquardt et al. 2014; Joseph et al. 2016)**.** Therefore, **Chapter 4** investigated the users' needs regarding light and acoustic conditions in nursing home environments. Users were both healthcare professionals as well as residents. The study was executed to develop a fitting strategy for lighting conditions and acoustical climate in the context of the healing environment concept. Challenging for those strategies were the specific user groups in both

experiments. There are different sets of priorities and needs concerning the indoor environment between the older adults suffering from dementia, the residents, and the healthcare professionals, the care providers (Eijkelenboom and Bluyssen, 2019). Besides, these needs and desires regarding the indoor environment showed to be conflicting. An example is the lighting conditions in nursing homes. Healthcare professionals need adequate and appropriate lighting to perform their daily visual tasks in day and night setting, while lighting conditions for residents should contribute to both visual tasks and non-image forming effects that support their circadian rhythm (Fisk, *et al.,* 2018; Khademagha *et al.,* 2016). The following question was therefore raised: "what is the optimum for the lighting conditions for both user groups (healthcare professionals and residents)?" The experiments contributed to gaining better knowledge about these desired conditions and how to solve conflicting requirements such to satisfy all users. For example, both the healthcare professionals and the residents prefered to create a homelike environment atmosphere with the light system. However, the position of the furniture in the common living room often changed and the position depended on the activities in the common living room. Based on this a homogenous lighting design was chosen, that is placed in conjunction with the roof. In this way healthcare professionals have more options to place the furniture aligned with the scheduled activities The different methods used in the (light, acoustic and indoor air quality) studies showed that it is valuable to look at both the indoor environmental measurements and the perception of the multiple user groups to design an intervention. The output of the interventions showed an improvement in the lighting conditions as well as in the acoustical climate of the common living room in the nursing home in the experiment. The vertical and horizontal illuminance levels in the common living room were significantly higher ($U=17.0$, $P=0.038$,s; $U=4.0$, $P=0.001$,s) and also the Correlated Colour Temperature Value were increased. In addition, a decreased of 50% in reverberation time and an increase of the STI of 0.12 was realised. The output of the exploratory study **(Subchapter 4.3)** showed that using the approach as a system to store information about the building and its indoor environment as well as tool to find the relations among building characteristics, indoor air quality and its effect on the transmission of infections. With a sufficient large sample size, the information stored in the systematic approach can then be used as a basis to derive correlations and define specific design guidelines for nursing homes.

A result of these interventions and exploratory study was insight in the design decision-making process for all involved user groups (residents, healthcare professionals and facility staff). Due to collaboration between the healthcare professionals, designer and facility managers, a better understanding was obtained of the required and desired lighting conditions and the acoustical climate from a healthcare professionals perspective.

Furthermore, insight was gained in how both groups share this knowledge with each other. Knowledge sharing was realised through following the structural approach **(Chapter 3)** in different discussion meetings where all involved user groups were present. The outcomes of the interventions as described in **Chapter 4.1 and 4.2** showed that the user (healthcare professionals) satisfaction was increased as well as the well-being of the residents. The obtained results showed that modifying the common living room via the indoor environmental factors, to the needs of the multiple user groups did have a positive effect on the overall outcome. Therefore, the indoor environmental factors could be counted as one of the factors in healthcare real estate decisions and integrated building design.

Nursing home decision makers showed that they strive for an attractive and inspiring environment **(Chapter 5)**. Therefore, besides financial aspects, the values 'increase satisfaction', 'quality of life' and 'participation' were highly appreciated outcomes. These values are connected to well-being and innovations in healthcare (e.g. 'healing environment'). 'Functionality', 'flexibility', and 'technology' were important attributes to achieve the ambitions of the nursing home organisations. It became apparent that the operationalisation of the strategic values of nursing home real estate creates more insight in the alignment process. Alignment means to select a fitting CRE strategy to help support corporate aims and ambitions (Appel-Meulenbroek and Haynes, 2014).

6.3 Theoretical and practical implications.

Due to the transition in healthcare legislation, it has become more important for nursing home decision makers to find a balance between the costs and revenues from the perspective of all user groups. It is recognised that there is growing interest to managing nursing home real estate as a strategic resource that should add value to the organisation. However, it still is a challenge to align corporate real estate strategies and decisions with core business strategies. Therefore, one of the main contributions of this thesis is that it focuses on integrated building design, where healthcare professionals, residents and decision-makers were involved in the decision process. In the thesis, an emphasis was on the benefits for healthcare professionals. In the context of a nursing home, this thesis showed how this type of facility should be taken into account as a physical work environment for healthcare professionals for the decision-making process as well. Nursing homes should not only be seen as a living environment for residents. It is known from the office sector that the indoor environmental factors lighting, acoustics and indoor air quality are important factors that affect health and comfort (e.g. Al Horr, *et al.,* 2016; Vimalanathan and Babu, 2014; Wolkoff, 2013; Bluyssen, *et al.,* 2011) and support the productivity of the employees. This thesis showed evidence that the indoor environmental

factors light, acoustic and indoor air quality also had a positive influence on the well-being of the healthcare professionals in the care environment. Furthermore, the results revealed that the improved acoustical climate supports communication among healthcare professionals and residents. It is recognised that effective communication enhances safety, social support, resident/staff satisfaction and quality of care (Gharaveis, et al. 2018). Thus, for nursing home decision-makers who aim to strive for an attractive and inspiring environment, it is recommended to create an environment that supports effective communication among healthcare professionals and residents. Furthermore, it is important to incorporate research findings in the accommodation strategy and translate these finding in building design.

A second strength of this thesis is the use of a structural participatory design approach. Over the past years, this method has been increasingly used in the field of healthcare (e.g. development of a technology) (Simonsen and Hertzum, 2012)). It has a lot to offer, such as clarification of aims and formulation of needs (Simonsen and Hertzum, 2012). The structural approach **(Chapter 3)** contributed to understanding the preferences for the indoor environmental factors by different user groups in a care setting. However, defining a strategy (e.g. lighting, acoustic, indoor air strategy) is still a challenging task for nursing home decision-makers. The interviews and observations **(Chapter 4)** improved the understanding of different demands and contributed to prioritising on different values (e.g. lighting conditions, acoustical climate, and indoor air quality). The results of the environmental interventions showed that personal and work-related characteristics (e.g. daily routine, the sensitivity of the physical environment or risk of infectious diseases) are also important aspects to define a real estate strategy. The systematic approach in **subchapter 4.3** can be used by nursing home decision makers to analyse the relation between the indoor air quality and the outbreaks of infectious diseases. Although the developed systematic approach is an effective way to involve multiple user groups in the design decision-making process, how to identify the underlying motives of decision-makers by this approach is still limited. A third strength of this thesis is therefore that it identifies which benefits nursing home decision-makers aim to achieve with their real estate through the use of the CNET method (a laddering technique). This method has been used in several research fields (e.g. for transportation choice behaviour) (Arentze, et al. 2008) to effectively explore underlying motives and choice behaviour, but hardly in the field of corporate real estate management. In addition, to our knowledge, it is applied for the first time in nursing homes in this thesis. The mental representations in **Chapter 5** (see, Figure 5.2 and 5.3) provide interesting results that give more insight into whether, and how and why nursing home decision-makers make choices in real estate alternatives. The results showed that it is important for nursing home decision-makers not only to focus on reducing costs or other

exchange values but also to consider the use value of their real estate. In contrast to exchange values, use values focus on user satisfaction and support. **Chapter 5** demonstrated that the focus was on the added use values quality of life, safety and freedom of choices. These results underline the importance of the transition to people in CRE research (Jylhä et al. 2019). The transition to people highlights the aim to provide a fit between user demand and CRE. Results from this thesis demonstrated how nursing home decision-makers can adapt the indoor
environmental conditions and systems to enhance the satisfaction and well-being of older people and support healthcare professionals during their work. Furthermore, the structural approach in **Chapter 3** confirmed that formulating and implementing a strategy is a continuous process (Konowalczuk and Ramian, 2014). Thus, nursing home decision-makers who aim to create a healthy environment should focus on collaboration with their stakeholders on a regular base to reflect on their planning and design. Reflecting together creates new insights and ideas and determines users' satisfaction with their environment.

6.4 Discussion of the findings; wider perspective

This dissertation revealed that a user-oriented focus to create healthcare facilities with a bottom-up approach is relevant to improve the decision-making process on strategic values for an accommodation strategy in healthcare real estate. However, previous studies highlight that there is a lack of a methodological approach that integrates the available evidence for healthcare facilities and its impact on their users' health and well-being (Zhang et al. 2019). This thesis contributes to the need for a holistic approach which considers the indoor environmental factors taken together and not separately.

Simonsen and Hertzum (2012) also showed the importance to integrate design and development with organisational implementation to obtain data and experiences from real use during design and development. This signals the importance of participation of multiple user groups in the initial phase, design phase and realisation phase, as described in **Chapter 3**, to gain more in-depth knowledge and to ensure that indoor environmental interventions get integrated in practice. For example, in the developed structural approach the various user groups were regularly informed about the changes in the environment and got the possibility to add their own view and new ideas or to react on the design proposals to ensure that changes are integrated in a relevant manner. Furthermore, it contributed to a holistic and dynamic perspective of the environmental factors due to the iterative process with the various user groups as important design partners to stimulate shared decision-making. This signals the importance for nursing home organisations to involve users regularly in the decision-making process with regard to the physical environment, to

monitor their satisfaction and for planning purposes.

This dissertation demonstrated that the holistic approach of the VAM model (Van der Voordt et al. 2016) fits as a usable framework to incorporate different needs of multiple user groups in the design and realisation of interventions in the environment for the benefits of its users (see Figure 6.1). This dissertation adds possible methods to gather information about the multiple user groups (e.g. residents, healthcare professionals and decisions makers) through the various steps of the VAM model. Furthermore, it contributes to creating a holistic and dynamic perspective and understanding of the indoor environmental factors in the decision-making process of healthcare real estate. Figure 6.1 shows an overview of the findings of this dissertation structured in the Value Adding Management (VAM) model. In **Chapter 2** and in **Chapter 5** the drivers to change and the required interventions (PLAN) were identified. The literature review and the laddering technique are useful methods to find these drivers and possibilities for interventions. The development of the structural approach in **Chapter 3** and the development of the interventions in chapter 4 forms the DO (See figure 6.1) in this model. These methods are useful to incorporate the required interventions and drivers in the real estate strategy of the healthcare organisation. The added value to involve healthcare professionals in the design decision-making process showed that the user needs were addressed and integrated to reach design solutions. **Chapter 4** described (through the interviews and observations) the output of the interventions and how these interventions changed the indoor environment of a healthcare facility (See CHECK in figure 2). In addition, **Chapter 4** gives information about the outcomes of the applied interventions. For example, the improved illuminance levels influenced the experience of the lighting conditions in the long-term care facility by healthcare professionals and residents. More residents were present and the residents seemed to be more active in the new situation (e.g. talking and reading). Thus, the added value to obtain data and experiences from a real use setting showed that shared decision making plays a relevant role in the design and planning process of nursing home organisations. The method as described in **Chapter 5** is useful to define (See PLAN in Figure 6.1) the focus in the decision-making process and to determine the priorities in real estate strategies.

In the field of offices, it is also recognised by organisations that their development depends on the building(s) they occupy (Lavy *et al.,* 2010; Tagliaro, 2018). Studies in office settings showed that being aware of how an office building performs is necessary to the core business management that takes place in that building, as well as to corporate real estate management and workplace strategies (Tagliaro, 2018). This signals the importance of nursing home organisations to measure and monitor building performance (See ACT in Figure 6.1). Therefore, it is necessary to have appropriate measuring tools. For future

research it is interesting to get more insight into performance measurements tools. Furthermore, how these tools may support nursing home organisations in the real estate decision-making process to determine whether to invest or to evaluate the appropriateness of facilities to ensure the alignment with the organisation's mission. For example, which real estate decisions stimulate more healthy environments to reduce absence, costs, and increase the well-being and quality of care.

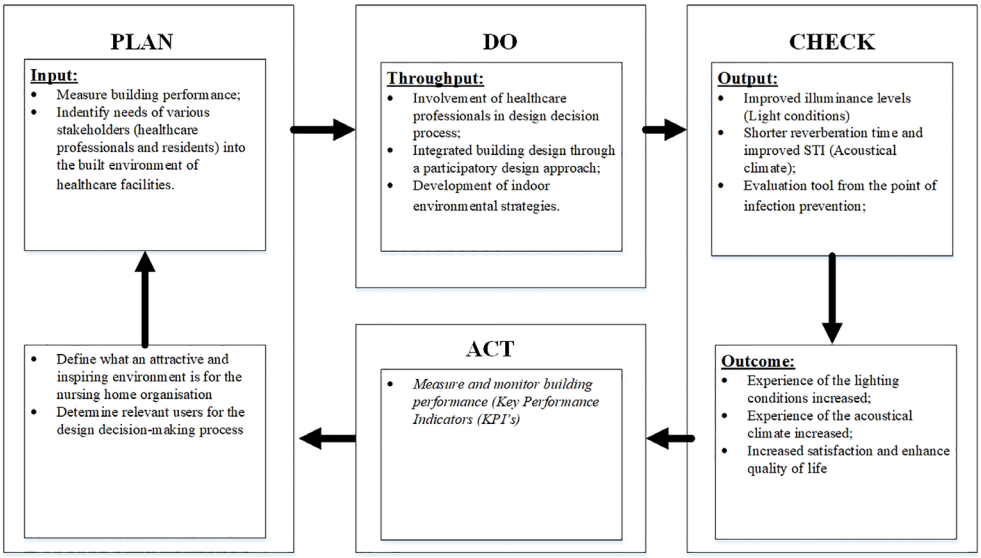

Figure 6.1. Overview of the findings of the thesis structured in the Value Adding Management model for nursing home decision-makers. It describes the different activities and the relation between the different activities to identify drivers to change. The "ACT" in the model describes a recommendation for future research.

Regarding addressing the impact of the physical environment on residents and staff of residential healthcare facilities, the literature review of Joseph et al. (2016) covers the most empirical evidence. Furthermore, it is known from the literature that increased overall light levels and improved acoustical climate are positively contributing to users' well-being and behaviour (Marquardt et al. 2014; Joseph et al. 2016). This dissertation confirmed that appropriate light levels and improved acoustical climate through a holistic approach will benefit healthcare professionals and residents. However, the preferences for the indoor environmental factors depend on personal factors (e.g. age, gender or personality) (Joseph et al. 2016), which also underlines the importance to integrate the knowledge of the care process. This is based not only on the expertise from healthcare professionals but also on the knowledge coming from experts in design. In addition, it is important to determine how particular choices regarding accommodation, facilities and services could benefit healthcare

professionals and residents. Complementary, this dissertation investigated how to optimise the indoor environmental factors (e.g. lighting, acoustical climate and indoor air quality) from users' perspective to adding strategic value to the nursing home organisation with their real estate.

6.5 Limitations in methods

Although this thesis provides interesting results of a user-oriented focus to create healthcare facilities and decision making on strategic values, many challenges for future research remain. In the developed structural approach **(Chapter 3)** the realisation step is not included as a separated step. It would be interesting for further development of the structural approach to add a separated step realisation in the approach with specific activities for the decision-makers. The interventions in the indoor environment (**Chapter 4**) were realised within a healthcare environment which has several advantages. For example, the entire building cycle was followed from the initial phase to the evaluation phase. Also, practical relevant outcomes for the healthcare organisation came forward during the development and realisation of the interventions. However, using a real-life care setting, as described in **Chapters 3 and 4**, led to several limitations in this study. To measure health outcomes of frail residents is still complex, because it also depends on non-built environmental related factors e.g. the quality of delivery of care. Furthermore, the population is frail and changed overtime. Thus, causal interpretations cannot be made. Although these causal interpretations cannot be made, the data retrieved from the interviews, observations and objective measurements revealed the relationships between the indoor environmental factors and health benefits. More research is needed to look at the direction of causal relationships. Furthermore, attention is needed for the side effects of the transitions in the real-life care setting. In this study, the three interventions (change of lay out, acoustical design and lighting design) were realised in one common living room. For the results in Subchapter 4.1, no account was made with the possible effect of the white panels on the whole ceiling on the illuminance levels and CCT values. In addition, in **Subchapter 4.1** only the illuminance and correlated colour temperatures (CCT) were determined in order to investigate potential light effects. Future research should include more light aspects (e.g. brightness, glare, reflectance) while performing a light effect study (van Duijnhoven et al. 2019). In addition, the moments for performing light measurements or the sample interval may depend on the lighting conditions (van Duijnhoven et al. 2019). Including continuous measurements over a longer period can give more information about the light effect because it gives more information about the range of lighting conditions and weather conditions over time. Also, the effect of tailoring lighting on the users' comfort and

preferences on their behaviour was not addressed in this study. Therefore, it would be interesting to analyse user characteristics and to develop profiles of these characteristics for set up guidelines for healthcare organisations. In **Subchapter 4.2** the focus was on the reverberations and speech intelligibility in order to investigate the influence on the experience of the acoustical climate in the common living room. Next research should include more research in the field of perception and annoyance caused by noise among older adults and healthcare professionals. In **Subchapter 4.3** an approach for the building assessment has been developed from the point of infection prevention. So, the parameters and scores have been defined to reduce transmission. The investigated parameters consist of different variables. However, the impact and the weighting factors of these variables are yet unknown. Therefore, it would be interesting to investigate whether weighting factors or hierarchy should be applied in the analysis of the parameters.

Using the CNET method in **Chapter 5,** a first step is made in describing the underlying motives and real estate decisions from the perspective of nursing home decision-makers. The context of the participants in this study differs from each other. The research design could be enhanced by including cases at the initiation phase, in order to make the underlying motives more specific for the nursing home sector. Next, the focus was on the CREM intervention 'changing the physical environment'. However, the focus on this intervention also led to several limitations. Other CREM interventions (e.g. changing facilities and services and changing the internal process and strategic advice and planning) could be important factors for nursing home decision-makers to achieve the ambitions of the organisations. Therefore, in future studies it is recommended to extend the CNET method with the other CREM interventions to gain more insight into the underlying motives of nursing home decision-makers.

6.6 Directions for future research

The structural approach **(Chapter 3)** has a user-oriented focus and a holistic approach. The approach includes a variety of methods and combining quantitative physical measurements and qualitative subjective assessments. Furthermore, it includes multiple user groups whereas the focus of literature in nursing home design and construction is mainly on a particular user group. This all retrieved more detailed information about the multiple user groups. Therefore, this framework is applicable for healthcare organisations to support their real estate decision-making process. It combines the different needs of multiple user groups. In further research it is recommended to extend this approach with other methodologies to obtain critical feedback from multiple user groups. This to develop

a more in-depth design decision-making model for healthcare organisations. For example, the users involved in our studies were not educated on their role and expectation for participation in a design team.
Also in the field of CRE, research has recognised that the shift to people will result in a better fit between user demand and real estate (Jylhä et al. 2019). This aim is provided through solutions such as personalisation, adjustments possibilities and freedom to choose (Jylhä et al. 2019). Further research on this topic needs to include these variables, which could result in a deeper understanding of the relationships between the built environment and health outcomes as well.

The role of human health and well-being plays a small role in the evolution of building standards (International Well Building Institute, 2019). The International Well Building Institute developed the WELL building standard which focuses on the people in the building. The Well Building standard is a continuously evolving programme and now there are pilot programmes to apply the WELL in a.o. healthcare environments (International WELL Building Institute, 2019). It is developed to prescribe how to design the physical environment in relation to general health and well-being of employees (International WELL Building Institute, 2019) and includes eight categories (e.g. air, light and comfort). This standard is based on evidence-based health and wellness interventions. For future research, it would be interesting to investigate if this tool is applicable for nursing home-decision makers. Furthermore, this thesis focused on user's needs, however it could be interesting to combine this with sustainable ambitions (e.g. energy savings). For example, De Bakker (2019) investigated occupancy-based lighting control to develop an energy-saving strategy that ensures office workers comfort. Also, in the field of nursing homes this is an interesting challenge for future research. For example, there is still a need for studies that need to examine implementing of both image forming (IF) and non-image forming (NIF) light requirements without compromising user comfort and energy consumption (Khademagha *et al.,* 2016). Furthermore, according to Reinten et al. (2017) a room acoustic design can be a strategy to control the sound environment in a workplace. This strengthens the need for a holistic approach to use indoor environmental factors (e.g. light, acoustical climate and indoor air quality) that potentially affect the well-being of both healthcare professionals and residents.

6.7 Conclusion

The corporate real estate management of Dutch healthcare organisations is shifting to managing real estate as a strategic resource that should add value to the organisation like other resources such as profits, human resources management, and technology. Furthermore, new insights regarding healthcare professionals and nursing home decision-makers have surfaced. This growing interest for building design as a means to shape healthcare environments that promote healing is based on the healing environments concept and evidence-based design. However, designing, creating or redesigning buildings is not a one size fits all solution because it depends on the context of the organisation and various needs and desires of the stakeholders. This thesis is devoted to developing a structural approach that takes into account the needs of the multiple user groups in the planning and design. Overall, this dissertation provided a deeper understanding of users' needs and the effects of the built environment on residents and healthcare professionals from the perspective of CREM. It opens up various new directions for future research in the area of healthcare, corporate real estate management and decision-making.

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Appendices

Appendix I chapter 4.3: Parameters

Appendix II chapter 4.3: Radar charts for each long term care facility

Appendix III chapter 4.3: Connection radar chart axes to investigated variables

Variable influencing infections	Which is influenced or characterized by:	Transmission		Reference
		Airborne	Contact	
Ventilation	_	Airborne		Li et al, 2007 [14]; Cole and Cook, 1998 [34]; WHO 2009 [17]; ASHRAE, 2012 [18]; Nielsen 2013 [23]; Eames et al, 2009 [21]
_	Ventilation rate	Airborne		Li et al, 2007 [14]; WHO 2009 [17]; Nielsen, 2013 [23]
	Air flow direction	Airborne		Li et al, 2007 [14]; Eames et al, 2009 [21]
_	*-room pressure differentials*	Airborne		ASHRAE, 2012 [18]
_	*-personalized ventilation*	Airborne		ASHRAE, 2012 [18]
_	*- displacement*	Airborne		ASHRAE, 2012 [18]
	Natural vs mechanical ventilation	Airborne		Seppänen and Fisk 2002 [35]
Temperature	_	Airborne		Cole and Cook, 1998 [34]
_	Heating	Airborne		Cole and Cook, 1998 [34]
	Remaining a constant temperature	Airborne		
Humidity	_	Airborne		Cole and Cook, 1998 [34]; Noti et al, 2013 [22]
_	Lack of moisture control	Airborne		Wargocki et al, 2002 [4]
Air cleaning	_	Airborne		ASHRAE, 2012 [18]; Cole and Cook, 2009 [34]
_	Filtrations	Airborne		ASHRAE, 2012 [18]; Eames et al, 2009 [21]
_	UV filtration	Airborne		ASHRAE, 2012 [18]
_	Air disinfection	Airborne		
_	PM	Airborne		
_	*0.5-5.0 µm droplets*	Airborne		Cole and Cook, 2009 [34]
_	*0.3-10 µm bacterial cells*	Airborne		Cole and Cook, 2009 [34]

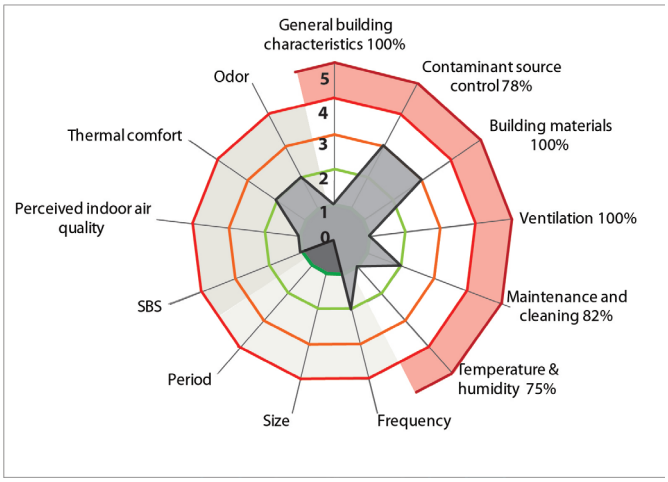
Appendix I. Parameters

	Questions in Building Checklist	Questions in HVAC Checklist	Physical measurements	Interview Use of building
				interview
		05;13-19	CO_2	
		03; 21; 21; 21;		
		01;02;04		
		40-46	indoor temperature	interview
		07;08		
	38-46	50-52		
		22;47-49	RH	
		23;24		
		06;10		
		30;31		
		32;		
		33;		
			PM10;2.5;0.7;0.5µm	
			PM2.5;0.7;0.5µm	
			PM10;2.5;0.7;0.5µm	

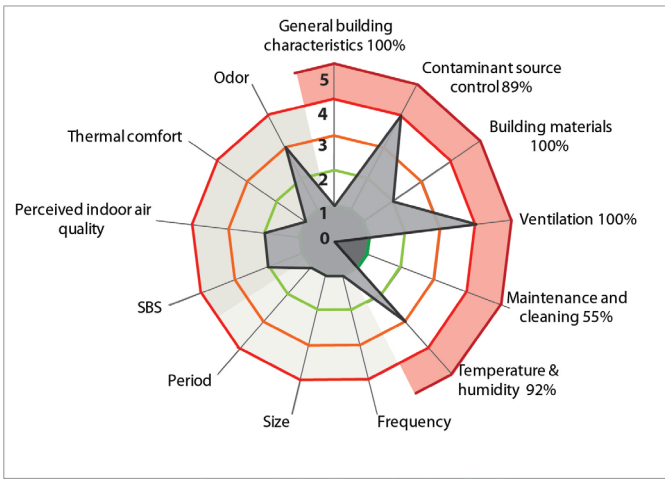
-	*0.02-0.30 µm viruses*	Airborne		Cole and Cook, 2009 [34]
-	Maintenance:	Airborne		Wargocki et al, 2002 [4], Salonen et 2013 [36]
-	Clogged filters	Airborne		
-	Contaminated ducts	Airborne		
Building materials	-	Airborne	Contact	Norbäck, 2009 [7]
-	Mold growth	Airborne	Contact	
-	Condensation	Airborne	Contact	
	Floor coverings	Airborne	Contact	
	Age of building and materials	Airborne	Contact	
Contaminant source control	-	Airborne		Norbäck, 2009 [7]
-	Source pollution reduction	Airborne		
	Location of outdoor air intakes	Airborne		
-	Outdoor concentrations	Airborne		Norbäck, 2009 [7]
Physical contact		Airborne	Contact	Li et al, 2007 [14]
-	Sharing facilities	Airborne	Contact	
	Seperation	Airborne	Contact	Garibaldi, 1999 [16]
	Space per person	Airborne	Contact	Li et al, 2007 [14]

		not possible	
	35-37; 33; 34;		
21;22;24;25; 27;28;30;31			
35;36;37 32;33 20;23;26;29 01;02;03;04			
34 15;16;17;18; 19	20;25-29		
07;12;13 05;06;14 08;09;10;11			interview interview

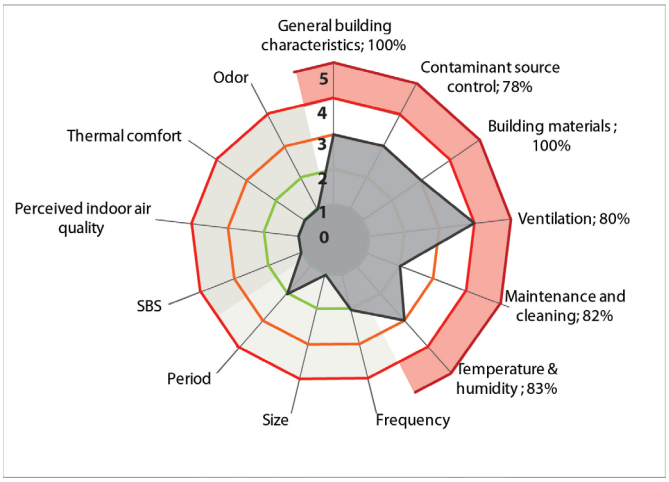
Appendix II. Radar charts for each long term care facility



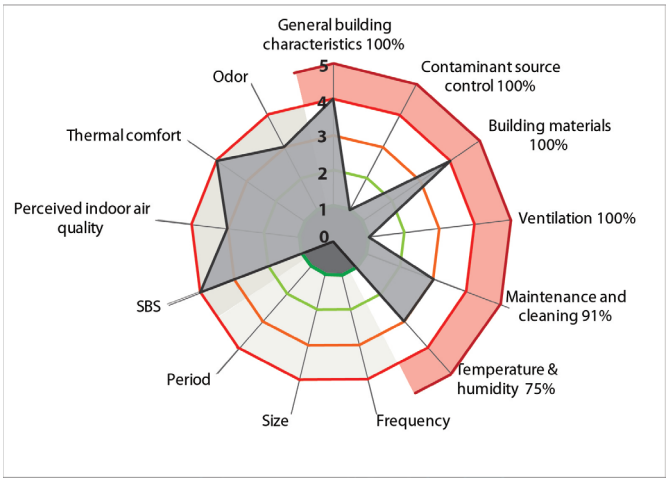
Long-term care facility A



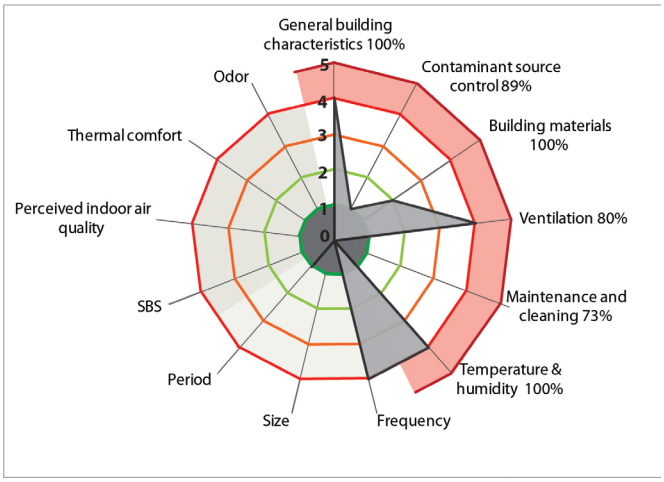
Long-term care facility B



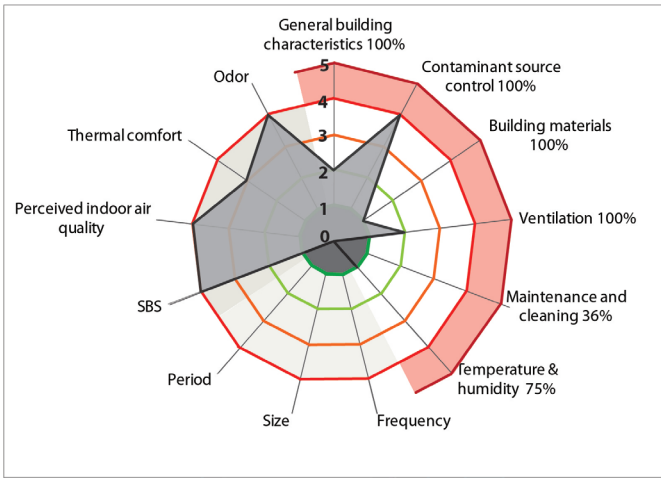
Long-term care facility C



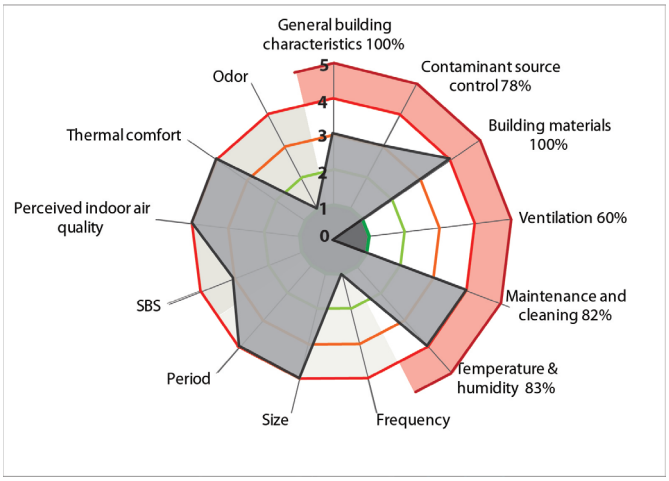
Long-term care facility D



Long-term care facility E



Long-term care facility F



Long-term care facility G

Appendix III. Connection radar chart axes to investigated variables

1. Building characteristics and HVAC characteristics

General building characteristics
The score of the "general" characteristics of the building consists of:

- *Age of buildings and materials, this score is average of:*
  - B#01 Year built
  - B#02 Year conversion of building (if not applicable: year is year built)
  - B#03 Year refurbishment (if not applicable: year is year built)
- *Space per person, score is average of:*
  - B#10 Average m^2 per person
  - B#11 Average m^3 per person
- *Separation residents, score is average of:*
  - B#05 Number of floor levels
  - B#06 Number of residential groups
  - B#14 Separation groups
- *Sharing facilities, score is average of:*
  - B#07 Number of residents in one group
  - B#12 Average number of bathrooms per person
  - B#13 Percentage with one persons room

Score "General"= ranking of the average score of
(Age of building and materials; Space per person; Separation residents; Sharing facilities)

Contaminant source control
The score of the "outdoor conditions" characteristics of the building consists of:

- *B#15 Location*
- *B#16 Outdoor pollutants*
- *Radiation, this score is average of:*
  - B#17 Radon
  - B#18 TV radio
  - B#19 Mobile phone
- *Position ventilation intake, this score is average of:*
  - HVAC#26 Position intake
  - HVAC#27a + b Distance exhaust

- HVAC#28a + b Distance cooling towers
- HVAC#29 Nr. of potential pollutant sources close to intake

Score "Contaminant source control" = ranking of the average score of (Location; Outdoor pollutants; Radiation, Position ventilation intake)

Building materials

The score of the "building materials" of the building consists of:

- *Material ceiling, score is average of:*
  - B#21 Ceiling living room
  - B#24 Ceiling kitchen
  - B#27 Ceiling bedroom
  - B#30 Ceiling corridor
- *Material floor, score is average of:*
  - B#20 Floor living room
  - B#23 Floor kitchen
  - B#26 Floor bedroom
  - B#29 Floor corridor
- *Material walls, score is average of:*
  - B#22 Walls living room
  - B#25 Walls kitchen
  - B#28 Walls bedroom
  - B#31 Walls corridor
- *Condensation*
  - B#32 Material window frames
  - Binom: - B#33 Condensation on windows
    - B#35 Visible mould growth
    - B#36 Damp spots on walls, ceiling or floors
    - B#37 Visible air leaks in the structure

Score "Building materials" = ranking of the average score of (Material ceiling; Material floor; Material walls; Condensation)

Ventilation

- *Air exchange rate, this score is average of:*
  - HVAC#01 Operable windows
  - HVAC#13b Design ACH living room
  - HVAC#14b Design ACH bedroom
  - HVAC#17a Measured ACH living room
  - HVAC#19a Measured ACH bedroom

Air cleaning

- *Air cleaning, this score is average of:*
  - HVAC#30a Filtration pre
  - HVAC#30b Filtration main
  -Binom: - HVAC#31 UV (binomial data)
  - HVAC#32 Air disinfection (binomial data)
- *Maintenance, this score is average of:*
  - HVAC#33 Frequency replacement filters
  - HVAC#34 Frequency cleaning supply air ducts
  - HVAC#35 Frequency supply air devices
  - HVAC#36 Frequency cleaning exhaust air devices
- *PM concentration, this score is average of:*
  - 10 µm average (measurements)
  - 2.5 µm average (measurements)
  - 0.7 µm average (measurements)
  - 0.5 µm average (measurements)

Temperature and humidity management

- *Remaining a constant temperature, this score is average of:*
  - B#38 Structure roof
  - B#40 Structure external walls
  - B#42 Structure internal walls
  - B#43 Structure floors
  - B#39 thermal resistance roof
  - B#41 Thermal resistance external walls
  - B#44 Thermal resistance floor
  - B#46 Percentage glazing
  -Binom: - HVAC#51abcd Solar shading (binomial data)
  - HVAC#42 HVAC (binomial data)
  - HVAC#43 Glazing (binomial data)
- *Heating and cooling, this score is average of:*
  -Binom: - HVAC#07 Heating in AHU (binomial data)
  - HVAC#08 Cooling in AHU (binomial data)
  - HVAC#44 Temperature controlled by the system (binomial data)
- *Humidity management, this score is average of:*
  - HVAC#22Humidification and dehumidification
  -Binom: - HVAC#23 Water droplet eliminators (binomial data)

- HVAC#24 Maintained to collect condensed water (binomial data)
- HVAC#47 Humidity controlled by the system (binomial data)

The binominal data within one category has been combined to determine a score. For each health care facility the number of positive answers at these questions are summed. The results of that summation has been treated like the other ordinal data to create a boxplot. From these results a score of each building can be defined, depending on the quartile the result is in.

B#01 means: question 01 from the building checklist.
HVAC#30 means: question 30 from the HVAC checklist.

2. Outbreaks of infectious diseases

Score "Frequency" = ranking of the score of frequency of outbreaks (number of outbreaks per year over the investigated period)
Score "Period" = ranking of the score of period of outbreaks (average number of days per outbreak)
Score "Size" = ranking of the score of size of outbreak (average number of persons [resident + professional] per outbreak)

3. Comfort and health

Score "Odor" = ranking of the score of (score odor [summer/winter] – PQ#39)
Score "Thermal comfort" = ranking of the score of (average % thermal acceptability [summer/winter] – PQ#30)
Score "Perceived Indoor air quality" = ranking of the score of (average % air quality acceptability [summer/winter] - PQ#36)
Score "SBS" = ranking of the score of (average #PSI5 symptoms/person [summer/winter] - PQ#12+#13)

PQ#01 means: question 01 from the personal questionnaire.

Dankwoord

Curriculum Vitae

List of Publications

Bouwstenen

Dankwoord

Taking my time' verwijst naar een prachtig lied geschreven door een jeugdvriendin. We vergeten soms even stil te staan in alle drukte van de dag. De tijd nemen om iets uit te laten rijpen, gunnen wij onszelf bijna niet. Dat is zonde. Sta soms stil bij alle bijzondere en mooie momenten die het leven ons te bieden heeft. Dit raakt ook de boodschap van dit proefschrift. Maak het leven een stukje aangenamer voor de doelgroep kwetsbare ouderen en de zorgprofessionals die deze doelgroep verzorgd. Hoe kunnen wij dat bereiken met een gebouw?

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Curriculum Vitae

Emelieke Huisman (Nijmegen, 1982) studied Architecture, Urbanism, and Building Sciences at the Delft University of Technology. She attained her master's degree in 2008 (major Real Estate and Housing) on a thesis about corporate real estate management of general hospitals. After completing her master's degree, she worked as a consultant advising organisations on implementing their sustainability ambitions (project management, masterplanning, programs of requirements, etc.). In 2010, Emelieke joined the research group Technology for Healthcare Innovations at Utrecht University of Applied Sciences as a researcher and lecturer in the field of real estate management and public health (engineering). She coordinates several courses for national and international students. In 2019, Emelieke joined the team of the Master of Urban and Area Development as a coordinator and lecturer. She attained her certificate of teaching skills (*Basiskwalificatie Didactische Bekwaamheid*) in 2012.

Whilst conducting her doctoral research, she attended international and national conferences on gerontechnology and healthy buildings. Her first article titled: "*Healing Environment: a review of the impact of the physical environmental factors on users"* that was published in Building and Environment is among the most downloaded papers of this journal. In 2015 she was a visiting researcher at the University of California Berkeley. She spent three months at the Center for Information Technology in the Interest of Society and the Banatao Institute (CITRIS). During her stay abroad, she successfully organised a seminar on "*Healing Environments: Dutch and US lessons learned*".

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In our continuously growing and ageing society, the demand for healthcare facilities and personalised care increases. This all will result in a rise in healthcare costs. Although healthcare is expensive, it is also valuable for the quality of life in an ageing society. Technological innovations (e.g. home automation), sustainability and the design of a 'healing environment' have become increasingly important for Dutch healthcare building design.

Understanding of building users' perception is also important for implementing concepts around 'healthy environments' (e.g healing environment, Mayo Clinic, Eden Alternative and Life Enrichment Care). This thesis focus on gaining a better understanding of the decision-making process of an accommodation strategy for nursing home organisations with a user-oriented focus and a bottom-up approach. This in order to contribute to support healthcare professionals in their work environment and to create an indoor environment suitable for frail older people needs and desires".

The indoor environmental factors lighting, acoustic and indoor air quality form the scope as a literature review showed that less is known about how indoor environmental factors in nursing home settings affects healthcare professionals and residents. Next, two experiments and one exploratory study were conducted to improve the indoor environmental factors of a common living room of a long-term care facility. The research continues to investigate the underlying motives and values that drives board and management, as decision-makers, for the nursing home real estate they manage.

In summary, this thesis shows a structural approach that takes into account the needs of the multiple user groups in the planning and design. Its provides a deeper understanding of users' need and the effects of the indoor environmental factors on residents and healthcare professionals from the perspective of corporate real estate management. It opens up various new directions for future research in the area of healthcare, corporate real estate management and decision-making.

DEPARTMENT OF THE BUILT ENVIRONMENT

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