Patient Preferences for Greenery Integration in Hospital Environments: A Stated Choice Experiment in a Dutch Healthcare Setting

Graduation Thesis

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Preface

Dear reader,

This thesis marks the completion of my double master program of the master track Urban Systems and Real Estate from the master of Architecture, Building and Planning, and the master Construction Management Engineering, both taught at the University of Technology in Eindhoven (TU/e). During my studies I discovered two interests; my passion for healthcare real estate and my fascination for the influence that the built environment can have on its users psychological state (environmental psychology). I combined both these interests in this master thesis; through the analysation of patient preferences of greenery integration within hospital environments. Hopefully, this thesis will contribute to creating hospitals which are more pleasantly for their patients and allow them to heal in a green environment.

This research would not have been possible without the collaboration of the Albert Schweitzer Hospital, which was enabled by the real estate consultancy firm RYSE. I would therefore like to thank Jeroen Heintzbergen, managing partner at RYSE, for making this collaboration possible and for getting me in contact with the infection prevention specialists. Additionally, I would like to thank my other colleagues from RYSE.

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Last, but not least, I would like to thank my family and friends who have unconditionally supported me during this graduation process, and the remaining of the six years of studying. A special thanks to the friends I gained throughout my studies who contributed to making my time spend in Eindhoven unforgettable.

I hope you enjoy reading this thesis and that it may inspire you.

Irene Zitzmann

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Summary

The integration of greenery in healthcare environments has been shown to reduce stress, enhance recovery and improve patient satisfaction. However, research into the relative preferences for different greenery interventions is still lacking.

This study aimed to identify which greenery interventions are valued most by patients and to translate these insights into a practical decision-making framework which allows for the creation of patient-centred hospital designs. A Stated Choice Experiment was conducted among members of the Albert Schweitzer Hospital patient panel to determine patient preferences for various green elements in patient rooms and hallways of the ward. In addition, expert interviews were conducted with two infection prevention specialists to assess the feasibility of implementing the various greenery interventions.

The results showed that patients strongly prefer hospitals with integrated greenery compared to those with white walls and no natural elements. The indoor garden was identified as the most preferred intervention by the respondents, followed by some elements located in the patient room; a large plant, a view of nature, vertical green and a nature poster. However, not all combinations of greenery interventions were equally appreciated, as some combinations were perceived as overwhelming or visually not compatible. This indicates the importance of selecting combinations thoughtfully, rather than a “more is better” approach.

Preferences also differed between patient groups. Patients with longer or more intensive stays valued greenery directly in their rooms more, while patients with shorter stays showed a larger preference for greenery in the common ward. Younger patients valued decorative nature elements more than elderly, while middle-aged patients placed more value on access to healing gardens. No significant differences were found between genders. The effect of the state of mobility (bed-bound or mobile) could not be determined due to the model deeming the data too singular.

Infection prevention currently restricts the placement of greenery or plants in patient rooms, therefore creating a gap between patient preferences and the practical feasibility of greenery integration. However, patients were found to also highly appreciate nature views and nature posters in their patient room, offering suitable alternatives. Additionally, infection prevention does allow the implementation of greenery or plants in the common ward, making the most preferred greenery intervention of a healing garden feasible to implement.

To support the creation of patient-centred designs, the results of the Stated Choice Experiment and the interviews were combined into a schematic decision-making framework and an Excel tool. This framework guides hospital administrators and healthcare real estate consultants in their decision-making concerning greenery integration by taking patient preferences and infection prevention into account.

Overall, this study contributes to both the academic field and practice by identifying the greenery interventions most appreciated by patients, quantifying their relative importance, analysing their feasibility in terms of infection prevention, and providing practical guidance for the creation of patient-centred hospital designs.

Samenvatting

De integratie van groen in zorgomgevingen blijkt stress te verminderen, het herstel te bevorderen en de patiënttevredenheid te verbeteren. Onderzoek naar de relative voorkeuren voor verschillende groeninterventies is echter nog beperkt.

Dit onderzoek had als doel om te identificeren welke groeninterventies door patiënten het meest worden gewaardeerd en om deze inzichten te verltaen naar een praktisch besluitvormingskader (decision-making framework) dat het ontwerp van patiëntgerichte zieekenhuizen ondersteunt. Een *Stated Choice Experiment* is hiervoor uitgevoerd onder de leden van het patiëntenpanel van het Albert Schweitzer Ziekenhuis om de voorkeuren van patiënten voor verschillende groene elementen en gangen van de afdeling te bepalen. Daarnaast zijn interviews gehouden met twee deskundigen op het gebied van infectie preventie om de haalbaarheid van de implementatie van de verschillende groeninterventies te beoordelen.

De resultaten laten zien dat patiënten ziekenhuizen met groenintegratie duidelijk prefereren boven omgevingen met witte muren en zonder natuurlijke elementen. De binnentuin werd geïdentificeerd als de meest gewaardeerde interventie, gevolgd door enkele elementen in de patiëntenkamer; een grote plant, natuuruitzicht, verticaal groen en een natuurposter. Niet alle combinaties van groeninterventies werden echter even positief beoordeeld; sommige combinaties werden als te druk of visueel niet goed passend ervaren. Dit benadrukt het belang van een zorgvuldige selectie van combinaties, in plaats van een “meer is beter”-benadering.

Voorkeuren verschilden ook tussen patiëntgroepen. Patiënten met een langere of intensievere opname waardeerden groen direct in hun kamer meer, terwijl patiënten met een kort verblijf een grotere voorkeur hadden voor groen in de algemene afdeling. Jongere patiënten waardeerden decoratieve natuurelementen meer dan ouderen, terwijl middelbare leeftijdsgroepen meer waarde hechtten aan toegang tot een binnentuin. Er werden geen significante verschillen gevonden tussen mannen en vrouwen. Het effect van de mobiliteitsstatus (bedgebonden of mobiel) kon niet worden bepaald, doordat het model aangaf dat de data te weinig variatie bevatte.

Infectiepreventie beperkt momenteel het plaatsen van groen of planten in patiëntenkamers, waardoor er een kloof ontstaat tussen patiëntvoorkeuren en de praktische haalbaarheid van groenintegratie. Patiënten bleken echter ook natuuruitzichten en natuurposters in hun kamer sterk te waarderen, wat een geschikt alternatief kan bieden. Daarnaast staat infectiepreventie de toepassing van groen of planten in algemene afdelingen wel toe, waardoor de hoogst gewaardeerde interventie, een binnentuin, haalbaar blijft om te realiseren.

Om de ontwikkeling van patiëntgerichte ontwerpen te ondersteunen, zijn de resultaten van het *Stated Choice Experiment* en de interviews gecombineerd tot een schematisch besluitvormingskader (decision-making framework) en een Excel tool. Dit kader helpt ziekenhuisbestuurders en zorgvastgoedadviseurs bij het nemen van beslissingen over groenintegratie, waarbij zowel patiëntvoorkeuren als infectiepreventie worden meegenomen.

In totaliteit levert dit onerzoek een bijdrage aan zowel de academische wereld als de praktijk door te identificeren welke groeninterventies door patiënten het meest worden gewaardeerd, hun relatieve belang te kwantificeren, hun haalbaarheid te analyseren in het licht van infectiepreventie, en praktische handvatten te bieden voor het ontwerpen van patiëntgerichte ziekenhuisomgevingen.

Abstract

Past research highlights the benefits of integrating greenery within healthcare environments, showing its potential to reduce stress, improve patient satisfaction and shorten recovery times. However, research into the relative preferences of patients for potential greenery integration is still lacking. This study therefore investigates patient preferences regarding different greenery interventions in hospital rooms and hallways. A stated choice experiment (SCE) was conducted among members of a Dutch hospital's patient panel. Respondents were presented with pictures of hypothetical hospital environments and asked to choose between two alternatives. The alternatives varied in physical attributes (e.g. presence of plants, colour of wallpaper and view). A total of 670 surveys resulted in 3,954 valid choice sets. The choice sets were analysed using a mixed model in NLOGIT 6, resulting in an indoor garden and a large plant in the patient room as the most preferred interventions. In addition, interviews with infection specialists were conducted to identify infection risks that the suggested greenery integrations bring, which concluded that the implementation of nature within the patient room is not feasible yet. Providing the room with a nature view or a nature poster are potential alternative measures that do not cause infection risks, while still increasing the patients' perceived value. The study concludes with a framework to guide the decision-making process in prioritizing greenery interventions to align with patient preferences.

Keywords: Hospital design, Patient preferences, Healing environment, Stated choice experiment, Greenery

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1. Introduction

Modern healthcare is shifting towards a holistic approach to health and well-being by emphasizing the treatment of the whole person rather than only addressing a set of symptoms (Ruby, 2024). Research highlights the benefits of integrating greenery within healthcare environments, showing its potential to reduce stress (Guidolin et al., 2024; Van Iperen et al., 2023; Zaťovičová and Kubáňová, 2024) improve patient satisfaction (Di Sivo & Balducci, 2019; Guidolin et al., 2024; Zaťovičová and Kubáňová, 2024) and shorten recovery times (Guidolin et al., 2024; Khan et al., 2016; Zhu et al., 2024). Greenery interventions in healthcare environments can range from indoor plants and healing gardens to natural views and depictions of greenery. However, practical barriers such as infection control may limit the extent to which greenery can be integrated into healthcare settings (St. Anna ziekenhuis, n.d.; Surial et al., 2021).

Despite the growing interest in this field, most studies have focused on documenting health outcomes associated with specific greenery interventions (Van Iperen et al., 2023; Zaťovičová and Kubáňová, 2024; Zhu et al., 2024). So far, only a few studies exist that examine patient preferences. For example, Chang and Chien (2017) investigated specific features that influence patients' visiting behaviour of natural landscapes surrounding hospitals, while Van Oel et al. (2021) analysed patient preferences for designs for single patient rooms, also including the option of a nature view and comparing the added value of a vase with bamboo to a painting. While these studies analyse patient preferences for certain green elements, they are limited in scope; Chang et al. (2017) only addressed external landscapes and Van Oel et al. (2019) compared a narrow set of design features for patient rooms. Additionally, neither investigated how preferences may differ per type of hospital stay. Moreover, little is known about how infection control concerns constrain the implementation of greenery interventions, despite hospitals often mentioning this as a barrier (Surial et al., 2021).

This highlights three key research gaps: (1) the comparison of patient preferences of different greenery interventions (e.g. plants, healing gardens, natural views) (2) the influence of length of stay and state of mobility (bed-bound or mobile) on patient preferences and (3) the applicability of greenery interventions within healthcare environments, particularly concerning the risk of infection. Understanding these preferences and potential barriers will enable hospital administrators to make evidence-based decisions regarding integration of greenery within the hospital design. Therefore, this study focuses on the following research questions: *(RQ1) Which types of greenery interventions in hospital environments do patients prefer? (RQ2) Does the length of stay or state of mobility (bed-bound or mobile) influence these preferences? (RQ3) Which types of greenery interventions are applicable regarding risk of infection?*

A mixed-method approach is used to answer these questions. This paper highlights key insights from literature and elaborates on the methodology in which the preferences of patients regarding greenery interventions will be measured through a stated choice experiment (SCE). Additionally, interviews with infection specialists are reported which identify infection related barriers for greenery interventions. The results of these are combined in a decision-making framework. The paper concludes by discussing the insights gained regarding patient preferences for greenery interventions, while also addressing limitations and potential directions for follow-up research. The findings will contribute to evidence-based recommendations for greenery integration in hospital designs.

2. Literature review

The integration of natural elements into healthcare environments dates back centuries. One of the earliest recorded examples of healing environments are the Asclepieia of ancient Greece, which were healing sanctuaries dedicated to Asclepios, the god of medicine (Encyclopaedia Britannica, 1999; Pavli & Maltezou, 2024). Their locations were carefully selected; idyllic sites, with lush vegetation, pleasant and relaxing views, abundant running water and sometimes even thermal springs. These sites were chosen to facilitate the spiritual healing aspect of the recovery process in which the ancient Greek believed (Pavli & Maltezou, 2024). Thus, the Asclepieia can be viewed as the forerunners of the provision of *holistic healthcare*, which not only addresses the biological dimensions, but also the psychological, familial, societal, ethical and spiritual dimensions of health and illness (Gordon, 1982). While historically originating from spiritual beliefs, the concept of holistic healthcare and healing environments recently emerged again in modern healthcare design to optimize patient outcomes (Pavli & Maltezou, 2024; Zhu & Sarah, 2024).

2.1 Direct effects of greenery on patients

Guidolin et al. (2024) presented a scoping review in which they included 41 studies and classified nature exposure in seven categories, ranging from natural window scenes to direct contact with nature and art depicting nature. While the systematic review also included interventions as nature soundscapes, virtual reality and presence of natural light, this paper focuses on physical and visual greenery interventions; the categories which were found to be most relevant to hospital design (Guidolin et al., 2024).

Past research has demonstrated that exposure to greenery positively affects a patient's (mental and physical) health and recovery. Ulrich (1984) initiated the (rediscovered) interest for research in *healing environments* (Zhu et al., 2024). In his study, he proved surgical patients facing a nature view to have shorter postoperative stays, needing fewer analgesics (painkillers) and receiving more positive nursing evaluations, compared to those with views of a brick wall.

These results were supported by later research; having the ability to see a real natural scene through a window showed positive effects on patient recovery and satisfaction levels (Guidolin et al., 2024; Zhu et al., 2024). Additionally, Timmermann et al. (2014) found that nature sights and natural light in the room were a powerful source of well-being, relief and hope for seriously ill hospitalized patients (inpatients). However, research on intensive care unit (ICU) patients suggests that nature views do not always yield measurable improvements in clinical outcomes, indicating that the type of stay may influence the effectiveness of integrating greenery (Kohn et al., 2013; Shepley et al., 2012).

Similarly, the presence of indoor plants in patient rooms has been linked to lower blood pressure, heart rate, and pain intensity, with 93% of patients identifying plants as the most positive feature of their hospital environment (Guidolin et al., 2024). Even imitation flowers, such as artificial potted roses, have shown to reduce anxiety and depression (Koh et al., 2018), suggesting that psychological perception plays a significant role in greenery-related benefits.

Additional to placing natural elements directly into patient rooms, research showed that integrating greenery in the public areas of the ward appeared similarly effective; more normal vital signs, less pain, fewer used analgesics and a reduced length of stay was reported (Khan et al., 2016). Additionally, all patients expressed positive opinions of the plants.

The presence of a healing garden in the public area has also been associated with improved patient outcomes. Healing gardens, defined by Ulrich (1999) as a specific space that contains features that have a consistent tendency to "foster restoration from stress and have other positive influences on patients, visitors, and staff or caregivers" (p. 30), have been widely recognized for their positive effects on patient well-being. Their presence has been associated with psychologically healthier patients who have shorter hospital stays, reduced anxiety and improved cognitive function, consequently also decreasing the need for medication and their related costs (Di Sivo & Balducci, 2019; Zaťovičová and Kubáňová, 2024). If there is limited space in the public areas to include greenery, implementing vertical greenery can be considered. According to Pérez-Urrestarazu et al. (2017), the participants of their study did not

have a clear preference between the implementation of conventional gardens or vertical greenery.

Researchers have also investigated whether artistic depictions of nature would yield similar benefits. Studies indicate that of the artistic depictions, natural landscapes and murals depicting trees were the most effective in lowering stress and normalizing heart rates and blood pressures (Guidolin et al., 2024). It was also found that showing nature images influenced mothers-to-be positively during labor (Aburas et al., 2016). However, these effects were found to be larger when implementing interventions that expose patients directly to actual greenery (Guidolin et al., 2024). Even though the results of the artistic depictions of nature seem more mixed, they may serve as viable substitutes in situations where physical greenery is not feasible, since patients still prefer them over no view of nature (Blaschke et al., 2016).

Moreover, studies showed the effect of colour schemes of patient rooms to influence the patients' comfort. It was found that patients prefer lighter hues for their rooms. Neutral palettes with soft natural tones (green, blue or brown) were found to be most effective in calming patients and their support system during their hospital stay (Kim, 2024).

So, to summarize, exposure to greenery has shown to positively impact patient outcomes by reducing stress, pain, anxiety and length of hospital stay (Guidolin et al., 2024; Ulrich, 1984; Zhu et al., 2024). Benefits are observed through direct exposure to greenery, such as window views (Guidolin et al., 2024; Timmerman et al., 2014; Zhu et al., 2024), indoor plants (Guidolin et al., 2024; Khan et al., 2016), vertical greenery (Pérez-Urrestarazu et al, 2017) and healing gardens (Di Sivo & Balducci, 2019; Zaťovičová and Kubáňová, 2024), as well as indirect exposure through artificial greenery (Koh et al., 2018) and artistic depictions of nature (Aburas et al., 2016; Blaschke et al., 2016; Guidolin et al., 2024) where living plants are not feasible. Additionally, the use of calming and natural color schemes within the hospital design helps patients and their support system to feel more at ease (Kim, 2024).

2.2 Downsides of greenery due to risk of infection

Despite its benefits, the implementation of greenery in hospitals presents challenges for infection control. Hospital-acquired infections (HAIs), infections that occur because of a stay, diagnosis or treatment in a hospital, affect approximately 7% of patients (Mascini & Troelstra, 2006; PREZIES, 2023). From the perspective of infection control, concerns are raised about microbial contamination associated with the presence of indoor plants. Surial et al. (2021) found elevated concentrations of microorganisms in the air, on the plant wall and in the water when assessing a vertical garden within a hospital. However, Moslehian et al. (2023) found no significant relation showing how and in what quantity indoor plants might lead to hospital-acquired infections is. Nonetheless, many hospital policies restrict plant use in high-risk areas, such as ICUs and neonatal units, indicating a hesitancy towards the implementation of (living) greenery (St. Anna ziekenhuis, n.d.).

Collectively, the studies consistently highlight the (therapeutic) benefits of integrating greenery in hospital environments. However, comparative studies evaluating different greenery interventions remain limited. While the importance of patient preferences is recognised in some studies, there appears to be limited evidence on patients' relative preferences regarding different greenery interventions. Additionally, hospital departments (the length of stay) appear to influence outcomes, with for example critically ill patients in ICUs showing less benefits of greenery interventions compared to general hospital patients (Kohn et al., 2013; Shepley et al., 2012). From the perspective of infection prevention, the length of stay is likely to also influence which types of greenery can be integrated.

Table 1 summarizes the main interventions and provides an overview of their reported effects in literature as discussed above.

Table 1: Overview conclusions literature review interventions

Intervention / barrier	*Literature*	*Main conclusions*
Window views of nature	Guidolin et al. (2024); Kohn et al. (2013); Shepley et al. (2012); Timmerman et al. (2014); Ulrich (1984); Zhu et al. (2024)	Resulted in shorter postoperative stays, reduced analgesic use, positive patient evaluations, improved well-being. Patient condition / department may influence effectiveness.
Indoor plants in patient rooms	Guidolin et al. (2024); Koh et al. (2018)	Associated with lower blood pressure, heart rate and pain intensity, and highly valued by patients. Even artificial plants reduce anxiety and depression, suggesting psychological perception is key.
Indoor plants in public areas	Guidolin et al (2024); Khan et al (2016)	Improve vital signs, reduces pain and analgesic use, shorten length of stay and is positively received by patients
Healing gardens	Di Sivo & Balducci (2019); Guidolin et al (2024); Zaťovičová and Kubáňová (2024)	Affiliated with psychologically healthier patients, who have shorter hospital stays, reduced anxiety, improved cognitive function and lower medication needs
Vertical greenery	Pérez-Urrestarazu et al. (2017)	Viewed as equally acceptable intervention compared to conventional gardens
Artistic depictions of nature	Aburas et al. (2016); Blaschke et al (2016); Guidolin et al (2024)	Lower stress, normalize heart rates and blood pressures and positively influence labour experiences. Effects are weaker compared to living greenery, but still preferable compared to no green exposure.
Colour schemes (natural tones)	Kim (2024)	Patients prefer light, neutral palettes with green/blue/brown tones. These colour schemes calm patients and their support system.
Risk of infection	Mascini & Troelstra (2006); Moslehian et al. (2023); St. Anna ziekenhuis (n.d.); Surial et al. (2021)	Indoor plants bring concerns about microbial contamination regarding hospital-acquired infections. Evidence inconsistent on actual infection outcomes. Hospitals often restrict plants in high-risk areas (e.g. ICUs and neonatal units).

This presents a research gap in the exploration of patient preferences on greenery interventions, as well as the influence of their type of hospital stay on this preference and the applicability of the greenery interventions. Research into infection-mitigation strategies, may help bridge the gap between scientific findings and institutional regulations, and allow for safe(r) greenery integration. Exploring these gaps will allow for evidence-based decisions regarding the integration of greenery in hospital design.

3. Methodology

3.1 Study population and data collection

The exploration of patient preferences for greenery interventions within hospital design (RQ1) and the influence of length of stay and state of mobility (bed-bound or mobile) on this preference (RQ2) was assessed through a stated choice experiment. This SCE was integrated in a broader survey distributed among the 2700 members of the patient panel of the Albert Schweitzer hospital (ASz), located in the Netherlands. This panel consists of people who were a patient of the hospital before 2023 and who voluntarily registered to the panel to take part in hospital-related surveys. Some of these panel members were active patients, meaning they still visited the hospital when the survey was distributed, while others were former patients. The survey was distributed in B1 level Dutch, ensuring that non-native Dutch speakers were more likely to be able to participate as well. The ethical protocols of Eindhoven University of Technology were followed for informed consent and data anonymity and the survey received ethical approval by the Ethical Review Board of the author's university (ERB2025BE29).

3.2 Stated choice experiments (SCE)

Stated choice experiments (SCE's) are a well-established method to quantify individual preferences (Louviere et al., 2000; Salampessy et al., 2022; Soekhai et al., 2018). Grounded in the Random Utility Maximization framework, SCE's assume that individuals will choose the alternative that maximizes their utility. In this approach, choices are collected from respondents across a series of hypothetical scenarios (choice sets). Each choice set consists of two or more alternatives, characterized by the same set of attributes, but differing in attribute levels. The choices of respondents will reveal the trade-offs they are (often unconsciously) willing to make between attributes.

SCE's are widely applied in areas such as marketing, transportation, and environmental management (Louviere et al., 2000). In health economics, the application of SCE's is seen to increase throughout the years (Soekhai et al., 2018). In other healthcare fields, SCE's are applied for healthcare decision-making as well (Huls & De Bekker-Grob, 2022; Jiang et al., 2020; Kløjgaard et al., 2012;). Furthermore, the method has been applied in research focused on patient preferences (Chang and Chien, 2017; Van Oel et al.; 2021), with the aim to generate evidence to support design decisions that focus on increasing patient well-being in healthcare environments. SCE's are increasingly supported with sophisticated and efficient experimental designs created with software programs such as NGENE (Soekhai et al., 2018).

In a SCE, a controlled environment is created, in which a set of attributes can be measured. The experiment can be distributed through a survey, allowing patients to participate without requiring physical presence. The method has proven to be suitable to identify trade-offs, sub-interests and weights people attach to certain attributes (information that is very useful for decision support in hospitals). Moreover, it has shown its value in previously conducted healthcare (preference) studies. Because of this, the SCE method was chosen for this research.

3.3 Attributes and levels

The attributes included in the SCE are based on the identified greenery interventions in the literature review. Five attributes and their levels were selected (see Table 2).

Table 2: Attributes and levels SCE

Attribute	*Location*	*Description*	*Levels*
(1) Window view	Patient room	The view the patient will have from the window perpendicular to the bed.	Brick wall, Nature view
(2) Plants / greenery	Patient room	The presence of plants or other greenery in the patient room.	No plants, large potted plant, vertical green, small potted plant
(3) Plants / greenery	Hallway ward	The presence of plants or other greenery in the hallway of the general ward.	No plants, potted plants, vertical green, indoor garden
(4) Wallpaper	Patient room	The colour/pattern of the wall facing the bed. All other walls are white.	White, Green, Wood, Nature poster
(5) Wallpaper	Hallway ward	The colour/pattern of the wall on one side of the hallway of the general ward. The other walls are white.	White, Green, Wood, Nature poster

Building on the study of Ulrich (1984), which compared the outcomes of patients recovering from surgery with either a brick wall view or nature view, the attribute *Window view* (1) was limited to two levels; *brick wall* and *nature view*. This comparison was also used in more recent research (Kohn et al., 2013; Shepley et al., 2012; Zhu et al., 2024).

The literature showed that a plant in the patient room was correlated with several health indicators (Guidolin et al., 2024) and that living green was preferred over artificial greenery (Koh et al., 2018). However, since it is hard to differentiate between artificial greenery and living plants in pictures, the distinction was not made in the SCE. Because the literature did not compare the preference of a *small plant* or a *large plant* (Guidolin et al., 2024), both were included to investigate this. Pérez-Urrestarazu et al. (2017) indicated *vertical greenery* as space-efficient solution in hallways. To allow for the comparison of placement and to keep the total number of different attribute levels that the respondent has to compare lower, this type of greenery was also included for the patient room. *No plants* was taken as a reference attribute level.

For the *Plants/greenery in the hallway of the ward* (3), the attributes ranged from a large *indoor garden* (Ulrich, 1999; Di Sivo & Balducci, 2019; Zaťovičová and Kubáňová, 2024), to *potted plants* (Khan et al., 2016) and *vertical green* (Pérez-Urrestarazu et al., 2017). *No plants* was again taken as reference attribute level.

Artistic depictions were identified as viable substitutes when physical greenery is not feasible (Blaschke et al., 2016), with murals of trees reported as most effective (Guidolin et al., 2024). Therefore, one of the attribute levels of the *Wallpaper in the patient room* (4) was the implementation of a nature poster. Additionally, colour schemes were shown to increase patient comfort, especially soft neutral tones, such as green, blue and brown (Kim, 2024). Therefore, *Green wallpaper* was taken as an attribute level and *White wallpaper* was taken as reference attribute level. Lastly, *Wood wallpaper* was selected as a middle ground between a poster and brown wallpaper.

As with patient rooms, colour and artistic depictions may influence the perception of the hospital when applied in the public hallways. Therefore, the same attribute levels were applied for the *Wallpaper in the hallway of the ward* (5). This again allows for comparison of placement preferences across locations and keeps the total number of different attribute levels that the respondent has to compare lower.

3.4 Experimental design

With four attributes of each four levels plus one attribute with two possible levels, a full factorial design would yield 512 ($4^4 \times 2^1$) different possible alternatives to be included. In order to optimize the feasibility of the research, without needing thousands of respondents, a fractional factorial design was created (Louviere et al., 2000) using NGENE software (Soekhai et al., 2018). This design is generated by an iterative search algorithm that seeks to minimize the covariance of the parameter estimates for the model, which increases the efficiency while minimizing the number of included alternatives (ChoiceMetrics, 2024).

Previous research mostly focused on the inclusion of only one greenery intervention (Guidolin et al., 2024; Van Iperen et al., 2023; Zaťovičová and Kubáňová, 2024; Zhu et al., 2024), not taking into account the implementation of multiple greenery interventions. This would suggest that implementing greenery interventions always yields positive values. However, these studies do not investigate what would happen if multiple greenery interventions would be implemented; whether the interventions reinforce the positive outcomes or whether combinations might exist where patients perceive it as too much, resulting in a decrease in value. Analysing interactions will therefore give more insight into the effects of implementing multiple greenery interventions and which combinations would be preferred.

In SCE's, an interaction occurs between two attributes if the preference of the respondent for levels of one attribute depends on the levels of the second. While main effects capture the independent contribution of each attribute, interactions allow for the examination whether attributes reinforce or weaken each other's impact (Louviere et al., 2000).

In this study, only interactions were considered within the patient room context, since this is the environment in which patients are likely to spend most of their time during their stay (especially for bed-bound patients). Specifically, the following effects were examined; (1) *the interaction between wallpaper and the presence of plants/greenery*, (2) *the interaction between wallpaper and the type of window view* and (3) *the interaction between the presence of plants/greenery and the type of window view*. These (two-way) interactions include all attributes that are located in the patient room.

The interactions were integrated in the code for NGENE. This resulted in a fractional factorial design with 113 unique profiles, combined into sets of 2 profiles to create 64 choicesets, which allowed for the analysis of the selected interactions.

3.5 Survey

The survey consisted of 23 questions and started with three demographic items; gender, age category and nationality. Additionally, respondents were asked which hospital department they visited the most frequently to allow for an estimation of the average length of stay per respondent. All personal questions also offered the respondent a "prefer not to say" option to respect their privacy.

To include the physical state of patients, without having to ask them this directly for their privacy, all patients were allocated to one of two scenarios that they had to keep in mind during the survey; they were either a *bed-bound* (not able to leave their bed) or a *mobile* patient.

The SCE part of the survey was titled *decoration of patient room and hallway* to try to limit bias by not including the word 'greenery' in the title. For the SCE, the respondent was presented four randomly selected choice sets out of the 64 generated in the fractional factorial design, after which the respondent could choose to fill in four additional randomly selected choice sets. The other questions of the survey are not relevant for this paper as they separately address other very different dimensions of hospital design.

In the SCE, each choice set showed the respondent two hypothetical hospitals, both represented by two images: one showing the patient room and the other depicting the hallway of the ward. Respondents were asked to indicate whether they would prefer to stay in Hospital A, Hospital B, or if they had no preference between the two.

The pictures were designed with the HomeByMe software (HomeByMe, 2025). The current design of patient rooms of the Albert Schweitzer hospital (the maternity ward) was taken as a reference (Albert Schweitzer ziekenhuis, 2013). The images were created from the perspective of a person walking (eyelevel of a person with 1.8m height, the average height of a Dutch person (Centraal Bureau voor de Statistiek, 2022)) for the hallways of the ward and of a person laying in bed (1.0m height) for the patient room. Adobe Photoshop was used for colour adjustment and to enhance the image quality of the pictures.

Figure 1 shows a choice set in Dutch, as presented to the respondent.

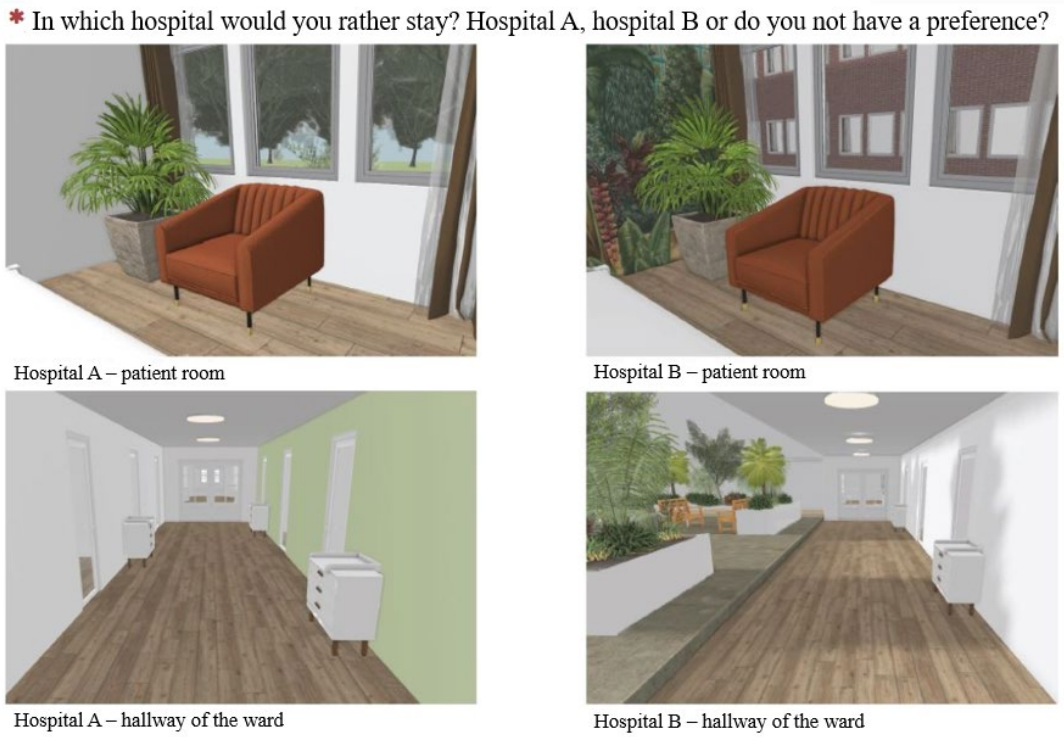

Figure 1: Example of choice set (translated from Dutch)

The survey was constructed in Limesurvey software. The members of the patient panel received an email from the KV&I (quality research and innovation department of the ASz) with an invitation and link to the survey on the 11th of June, 2025. Respondents were evenly allocated to the bed-bound and mobile scenarios and randomization was used to select four or, if the respondent was willing to continue, eight choice sets.

3.6 Response

The survey remained open for two weeks, during which 671 respondents completed the stated choice experiment (response rate of 25%). One response was excluded, as the respondent indicated they were not a (former) patient, but visited the hospital solely for work related activities. Of the 670 respondents, 328 (49%) chose to answer four additional choice sets. A total of 25 choice observations were removed due to technical error, causing no choice being recorded in the stated choice experiment and therefore deemed invalid. This resulted in a total of 3,954 valid choice observations.

During the analysis, the hospital departments were clustered together with a healthcare expert on their most occurring length of stay. This resulted in four department clusters; *(1) Short-term stay (1 day) and day treatments, (2) Medium-term stay (2-5 days), (3) Long-term stay (>5 days) and (4) (Often) short, but intensive stay* (Table 3).

Table 3: Department clusters

Cluster	*Departments*
Short-term stay and day treatment	GP post, ENT, Dermatology, Breast clinic, Day treatment, Pain clinic, Sleep clinic, Ophthalmology
Medium-term stay	Surgery, Gynaecology, Internal medicine, Urology, Gastroenterology, Orthopaedics, Paediatrics
Long-term stay	Oncology, Haematology, Geriatrics, Rehabilitation, Rheumatology, Psychiatry
(Often) short, but intensive stay	Cardiology, Neurology, Pulmonology

As presented in Table 4, 92% of the respondents were over 45 years old, while this is only 70% for general Dutch hospital admissions (Volksgezondheid en Zorg, 2025). Additionally, 99% of the respondents held a Dutch nationality, making the respondents less representative for the 34% non-Dutch inhabitants of Dordrecht (Centraal Bureau voor de Statistiek, 2025), the city where the hospital is located. The male-to-female ratio was approximately equal.

There was considerable variation in length of stay, with the departments classified as *Cluster 2,* medium-term stay (2-5 days), being the largest group with 30% and the departments classified as *Cluster 3*, long-term stay (>5 days) as the smallest group with 19%. It can therefore be concluded that the sample represents a wide range of length of stay.

To conclude, compared to the population of Dordrecht (Centraal Bureau voor de Statistiek, 2025), and the national numbers of hospital admissions (Volksgezondheid en Zorg, 2025), the respondents were not fully representative. The sample specifically underrepresented individuals under 45 and individuals with a non-Dutch nationality. However, this corresponds with the underrepresentation of these individuals in the patient panel, which was indicated by the KV&I (quality research and innovation department of the ASz).

Table 4: Characteristics of respondents

Characteristic	*Percentage study sample (n=727) %*	*Percentage population Dordrecht %*	*Percentage hospital admissions Netherlands %*
Age category			
18-25	0.4	N.D.*	N.D.
26-45	7.9	26.5	15.8
46-65	35.5	26.7	25.9
>65	56.0	20.0	43.2
Would rather not share	0.2	N.A.**	N.A.
Gender			
Male	45.7	49.6	47.2
Female	53.9	50.4	52.8
Other	0.0	N.D.	N.D.
Would rather not share	0.4	N.A.	N.A.
Nationality			
Dutch	98.8	65.9	N.D.
Belgian	0.2	N.D.	N.D.
German	0.2	N.D.	N.D.
Other	0.5	N.D.	N.D.
Would rather not share	0.3	N.A.	N.A.
Department cluster			
Cluster 1: short-term stay (1 day) and day treatments	21.9	N.D.	N.D.

Cluster 2: medium-term stay (2-5 days)	29.5	N.D.	N.D.
Cluster 3: long-term stay (>5 days)	19.0	N.D.	N.D.
Cluster 4: (often) short, but intensive stay	26.6	N.D.	N.D.
Would rather not share	3.0	N.A.	N.A.

**N.D. = no data available **N.A. = not applicable*

3.7 Explorative multinomial logit model

The SCE-data was analysed using NLOGIT 6 software. To prepare the data extracted from LimeSurvey, Microsoft Excel was used to clean the data. For all socio-demographic questions, the department clusters, the scenarios and all attributes, dummy coding was used. For the dummy coded attributes, the non-nature attribute levels (white walls, no plants and no nature view), were taken as the reference levels. The departments of patients were clustered to form four clusters (of which three dummy variables were used, with *Cluster 1, short term stay* as reference category).

In the NLOGIT 6 software, first, an explorative multinomial logit model (MNL) was calculated. An MNL model analyses characteristics of individuals and the choices they make. Since SCE assume that individuals choose the alternative that maximizes their utility (Louviere et al., 2000; Salampessy et al., 2022; Soekhai et al., 2018), the MNL model calculates the probability of an individual choosing alternative *i* out of j possible alternatives as

$$P_{ni} = Prob\left(U_{ni} > U_{nj}\right), \forall\, j \neq i \qquad (1)$$

where the utility U_{nj} is defined as

$$U_{nj} = V_{nj} + \varepsilon_{nj} \qquad (2)$$

In the logit choice probability, only the representative utility V_{nj} (the observable component of utility) is included, which is usually specified to be linear in parameters: $V_{nj} = \beta' x_{nj}$ (Greene, 2016; Train, 2009). The logit choice probability is therefore given by the expression

$$P_{ni} = \frac{exp\,(\beta' x_{ni})}{\sum_j exp\,(\beta' x_{nj})} \qquad (3)$$

where x_{nj} contain the explanatory variables that describe the attributes of the alternative *j* and the characteristics of the individual *n* which might affect their choice behaviour. The relative importance of the attributes are captured in vector *β* (Greene, 2016; Train, 2009).

The MNL model yielded a Log likelihood function of -1,861.17. The model was compared to the constraints-only model, a model which only includes a constant and no other variables. The constraints-only model yielded a Log likelihood function of -4,084.06, indicating that the MNL model could be considered a significant improvement. The MNL model further had a McFadden pseudo R-squared value of .544, indicating an excellent overall model fit (Hensher et al., 2015).

3.8 Mixed logit model

Based on the assumption that the (former) patients of the patient panel will differ strongly in opinions and therefore their preferences as well, next, a mixed logit (ML) model was explored. This model is a generalized version of the MNL. Contrary to the MNL model, the ML model allows coefficients to vary across respondents, which accounts for unobserved preference heterogeneity (Henscher et al., 2015). This allows a more accurate representation of individual-level preferences within the choice context.

The probability of an individual choosing alternative *i* out of *j* possible alternatives is calculated by the mixed logit model as

$$P_{ni} = \int \left(\frac{exp\,(\beta' x_{ni})}{\sum_j \exp\,(\beta' x_{nj})} \right) f(\beta) d\beta \qquad (3)$$

where the mixed logit probability is calculated as a weighted average of the MNL formula, where β varies across individuals according to the distribution of $f(\beta)$ (Greene, 2016; Train 2009)

To test which coefficients could be included as randomized coefficients, first an explorative ML model was executed using 250 Halton draws. All randomized coefficients, except for *No Choice*, were found to have significant variance and could therefore be considered as random variables. As a next step, the *No Choice* variable and interactions were included as non-random variables. The final ML model was estimated using 2000 Halton draws and 55 iterations (of the allowed maximum of 200 iterations) to analyse the data of the 3,954 choice observations.

The final model yielded a Log likelihood function of -1,615.22, a significant improvement compared to the MNL model (-1,861.18). The model had a McFadden pseudo R-squared value of .628, indicating an even better overall model fit.

3.9 Interactions

In addition to analysing the main effects, interactions were included in the MNL and ML model. These interactions were predefined when developing the SCE in NGENE to avoid multicollinearity. The utility of alternative *i* for respondent *n* was therefore expressed as

$$\begin{aligned} U_{ni} = \beta_1 x_{1,ni} + \beta_2 x_{2,ni} + \beta_3 x_{3,ni} + \beta_{12}(x_{1,ni} \times x_{2,ni}) \\ + \beta_{13}(x_{1,ni} \times x_{3,ni}) + \beta_{23}(x_{2,ni} \times x_{3,ni}) + \beta_4 x_{4,ni} \\ + \beta_5 x_{5.ni} \end{aligned} \qquad (4)$$

where x_1, x_2 and x_3 represent the dummies of the attributes concerning the patient room; the wallpaper, greenery/plants and view (Table 2). The interaction terms β_{12}, β_{13} and β_{23} indicate whether the attribute levels reinforce or weaken each other's effects on the utility that the alternative brings the individual *n*. For the attributes concerning the hallway of the ward ($\beta_4 x_{4,ni}$ and $\beta_5 x_{5,ni}$), only the main effects are included, since the interactions were not included in the model (ChoiceMetrics, 2024; Greene, 2016; Train, 2009).

Influence of characteristics of respondents

To analyse the influence of characteristics of the respondent, the socio-demographic information (*age category, gender, nationality*), the department clusters and the given scenario (*mobile* and *bed-bound)* were analysed through the conduction of separate ML models. These models were estimated with 200 Halton draws and a maximum of 200 iterations to limit calculation time. The dummy variables of the characteristics were included as factors in the random parameter (Greene, 2016). All dummy variables per characteristic (e.g. ages 18-25, ages 26-45 and ages 46-65) were included in one model to allow the coefficients to be interpreted as relative to the reference variable (e.g. ages 65+). The inclusion of these characteristics allows interpretation of how preferences regarding greenery integration may vary across patient groups relative to their reference category.

3.10 Data collection about risks of infection

To further explore the potential risks of infection that may rise from greenery integration within a hospital environment (RQ3), two semi-structured interviews were conducted with infection prevention specialists. Both specialists possessed over 20 years of professional experience within the field.

The interviews were structured to gain insight on the topic at two levels. First, overarching considerations of infection prevention in relation to greenery integration within hospital environments were addressed. The focus of these considerations was identifying the most

critical risks associated with greenery integration. Secondly, more specific greenery interventions and their possible implementation were discussed. This included the types of greenery that might be possible to implement, the locations where greenery is allowed to be implemented and potential alternatives that could potentially offer similar benefits, while ensuring infection prevention.

3.11 Decision-making framework

To guide the choice of greenery interventions and translate the findings into practice, a decision-making framework was developed. The aim of this framework is to offer experts involved in the development of hospitals a practical tool to guide them in selecting greenery interventions to create patient-centred hospital designs.

The decision-making framework was based on the results of the stated choice experiment, combined with the insights on risks of infection. The framework guides the user through the possible greenery interventions by asking them to study the most preferred greenery intervention by patients, making a decision whether to implement this intervention and whether the user would like to implement more interventions. By asking the user questions regarding infection control regulations, the framework incorporates the infection risk assessment of the infection specialist, while keeping the framework timeless by not restricting any interventions that are not allowed yet. Additionally, the interaction effects were included, ensuring the framework to prevent certain combinations of greenery interventions to be made if the combination would reduce the overall utility score.

3.12 Validation process

In order to validate the framework, eight consultants specialized in healthcare real estate were invited to test it. Each consultant individually applied the framework for five different (hypothetical) scenario's, which were designed to include different parts of the framework. Since the consultants all worked at a Dutch real estate consultancy firm, the framework was translated to Dutch to overcome potential language barriers. Even though the consultants had to perform the tasks individually, they were located in the same room and could ask clarification of the researcher when necessary.

Each scenario included predefined constraints; *Whether infection prevention regulations would allow for plants within the patient room? Whether nature was present on the plot? How many measures (greenery interventions) they were allowed to implement?* and *Which measures they explicitly did not want to implement?*. Based on these constraints, only one possible path through the framework should be followed and all consultants should be led to one specific combination of greenery interventions. The consultants were asked to individually draw these paths for all five scenarios. This allowed for verification of the internal consistency of the framework.

Additionally to testing the scenarios, the consultants were asked to provide feedback on the framework. They were asked whether the framework was intuitive and easy to use or if any steps or terms were unclear or ambiguous. After the validation process, alterations were made to accommodate the feedback, which let to the framework being translated into a more practical Excel tool.

4. Results

4.1 Effects of the attributes

As presented in Table 5, the ML model resulted in all attributes being significant at a 1% significance level (p-value < 0.01) and to have the expected sign, indicating that all attributes create additional value compared to the base scenario (*white walls, no plants, no view*). The attributes all show a large standard deviation, confirming the presence of unobserved heterogeneity.

The *indoor garden* is the most influential attribute with a coefficient of 5.21, followed by the presence of a *large plant within the patient room* (coefficient of 4.71). Other preferred attributes were having a *nature view* (3.24), *vertical green* (2.87) and a *nature poster* (2.63) within the *patient room*. So while the presence of an indoor garden is preferred the most, the following preferred attributes are all located within the patient room, making it more dominant than the hallway, if no indoor garden is present.

Of all attribute levels, the *indoor garden* is deemed most valuable of all plants/greenery in the hallway of the ward, while a *large plant* is preferably present in the patient room. For both the hallway of the ward and the patient room, a *nature poster* is the most preferred type of wallpaper. Moreover, a *nature view* is strongly preferred over a view of a brick wall.

Table 5: Schematic representation decision-making framework

Attribute	*Location*	*Coefficient*	*Std. Error*	*Std. deviation (z)*	*Significance (p-value)*
Indoor garden	Hallway ward	5.20878***	.63982		
Large plant	Patient room	4.70847***	.56528	8.33	.0000
Nature view	Patient room	3.24477***	.45405	7.15	.0000
Vertical green	Patient room	2.87232***	.50404	5.70	.0000
Nature poster	Patient room	2.62583***	.37683	6.97	.0000
Small plant	Patient room	2.48080***	.45154	5.49	.0000
Potted plants	Hallway ward	1.84901***	.28372	6.52	.0000
Green wallpaper	Patient room	1.66616***	.43184	3.86	.0001
Vertical green	Hallway ward	1.46235***	.28210	5.18	.0000
Nature poster	Hallway ward	1.34967***	.63982	8.14	.0000
Wood wallpaper	Patient room	1.19392***	.38036	3.14	.0017
No choice	N.A.	1.09663***	.15375	7.13	.0000
Green wallpaper	Hallway ward	1.00457***	.24756	4.06	.0000
Wood wallpaper	Hallway ward	.83257***	.23883	3.49	.0005

** p-value < 0.1 ** p-value < 0.05 *** p-value < 0.01*

4.2 Interaction effects

Of the fifteen included interactions, eight were statistically significant (Table 6). Their coefficients were all negatively signed, indicating that the combination of attribute levels is not preferred by respondents. The presence of a *nature poster* yielded a reduced preference for the presence of plants/ greenery (*large plant, small plant, vertical green*) or a *nature view*. Additionally, a decrease in value was observed for *wood* or *green wallpaper* when a *large plant* was present in the patient room. The rooms with *wood* or *green wallpaper* also indicated a weaker preference for a *nature view*.

Table 6: Effects of the interactions between attributes of the alternatives

Attribute 1 (patient room)	*Attribute 2 (patient room)*	*Coefficient interaction*	*Coefficient attribute 1*	*Coefficient attribute 2*	*Significance Coefficient interaction (p-value)*
Wood wallpaper	Small plant	.16939	1.19392***	2.48080***	.7933
Nature poster	Large plant	–2.82028***	2.62583***	4.70847***	.0000
Wood wallpaper	Large plant	–2.65125***	1.19392***	4.70847***	.0000
Nature poster	Vertical green	–2.43529***	2.62583***	2.87232***	.0001
Green wallpaper	Large plant	–1.75278**	1.66616***	4.70847***	.0135
Nature poster	Small plant	–1.33011**	2.62583***	2.48080***	.0339
Nature poster	Nature view	–1.09146**	2.62583***	3.24477***	.0133
Wood wallpaper	Nature view	–.98431**	1.19392***	3.24477***	.0260
Green wallpaper	Nature view	–.82778*	1.66616***	3.24477***	.0599
Green wallpaper	Small plant	–.75306	1.66616***	2.48080***	.2451
Nature view	Small plant	–.69887	3.24477***	2.48080***	.1125
Nature view	Large plant	–.62812	3.24477***	4.70847***	.2094
Nature view	Vertical green	–.61971	3.24477***	2.87232***	.1993
Wood wallpaper	Vertical green	–.18620	1.19392***	2.87232***	.7900
Green wallpaper	Vertical green	–.12671	1.66616***	2.87232***	.8645

When comparing the coefficient of the interaction with the coefficients of the individual attributes it is found that, in most cases, implementing two attributes together still generates more value for respondents than implementing only one. This holds even when respondents do not explicitly prefer the attributes in combination, suggesting that the positive main effects outweigh the negative interaction effect.

However, if a patient room has a *large plant*, respondents prefer white walls (the base scenario) over the implementation of *a nature poster* or *wood wallpaper*. The coefficient of the interaction between these attributes is seen to have a negative value of a larger magnitude (–2.82) than the coefficient of a nature poster (2.63); indicating that it is better not to implement a nature poster if a large plant is included in the room (Figure 2). This is also the case for wood wallpaper, with an interaction coefficient of –2.65 and the coefficient of wood wallpaper being 1.19.

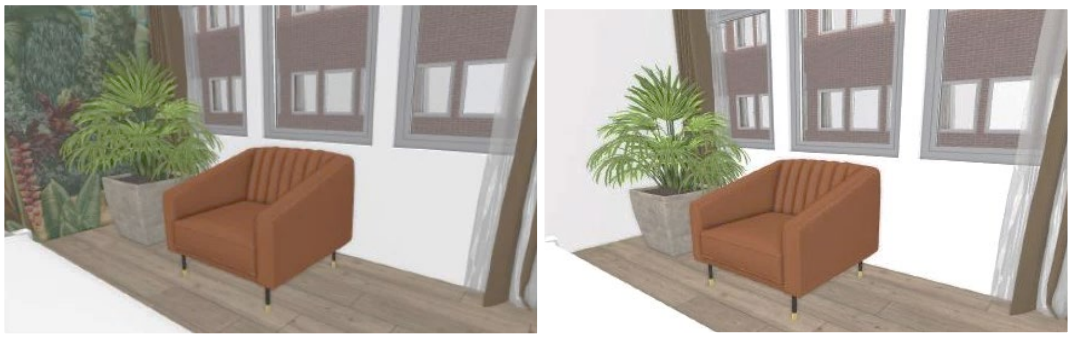

Figure 2: Patient room with nature poster and large plant (left) and patient room with only a large plant (right); the respondents would prefer the picture on the right over the picture on the left

The coefficients of *a nature poster* (2.63) and *wood wallpaper* (1.46), however, were larger than the coefficients of the other interactions, indicating that patients would still prefer to have a nature poster or wood wallpaper over white wallpaper, when vertical green, a small plant or nature view is present in the room. Patients also still preferred *green wallpaper* (1.67) over *white wallpaper* when a nature view or large plant was present.

4.3 Effects of the clusters

From the three clusters attributes, eleven combinations gave significant results (Table 7). The clusters 2, 3 and 4 were compared to cluster 1 (*Short-term stay and day treatments*). It was observed that Cluster 1 shows a relatively weaker preference for a large plant in the patient room, since all other clusters showed positive significant coefficients.

The respondents of Cluster 2, *Medium-term stay (2-5 days),* placed relatively more weight on the green wallpaper in the hallway as well, while they valued a nature view and nature poster in the patient room less than Cluster 1.

Respondents classified as Cluster 3, *Long-term stay (>5 days),* and Cluster 4, *(Often) short, but intensive stay,* valued a healing garden significantly less than respondents of Cluster 1. A nature poster in the hallway, on the other hand, was preferred more by respondents of Cluster 2 and 3.

For the remaining clusters and attributes, the heterogeneity coefficients were not statistically significant, indicating that their preference for attributes (levels) does not significantly differ from the respondents of Cluster 1. It can therefore be concluded that the impact of length of stay on preferences regarding greenery integration is selective rather than universal; some attributes, e.g. large plant in the patient room and healing garden, vary with stay duration, while the preferences for other attribute levels remain similar across clusters.

Table 7: Significant effects of the department clusters on the choice observations

Cluster	*Attribute level*	*Location*	*Coefficient*	*Std. Error*	*Significance (p-value)*
Cluster 2	Green wallpaper	Hallway	1.43846***	.51044	.0048
Cluster 3	Nature poster	Hallway	1.31020**	.60294	.0298
Cluster 2	Large plant	Patient room	1.29431**	.55167	.0190
Cluster 3	Large plant	Patient room	1.09448*	.64511	.0898
Cluster 4	Large plant	Patient room	.99169*	.54567	.0692
Cluster 2	Nature poster	Hallway	.91225*	.52913	.0847
Cluster 2	Nature poster	Patient room	–.87295*	.48378	.0712
Cluster 3	Vertical green	Hallway	–1.00956*	.57852	.0810
Cluster 3	Healing garden	Hallway	–1.47393*	.83697	.0782
Cluster 2	Nature view	Patient room	–1.48984***	.51447	.0038
Cluster 4	Healing garden	Hallway	–1.57845**	.71538	.0274

4.4 Effects of gender

No significant differences were found between male and female respondents, suggesting that gender is not a determining factor in preferences for greenery integration.

4.5 Effects of age

To investigate the effects of age on greenery integration preferences, the respondents over 65 years old were taken as a reference group. The respondents aged 18-25 turned out to be too singular. This could be explained by the relative small sample size of this group (only 0.4% of the responses). Therefore, the respondents aged 26-45 and 46-65 were compared to the reference group of respondents over 65 years old.

The respondents aged 26-45 showed significantly higher preferences for wallpaper, *green wallpaper, wood wallpaper* and *a nature poster,* in the patient room compared to respondents over 65 years old (Table 8). Respondents aged 46-65 only showed to value a healing garden significantly higher than older patients.

Table 8: Significant effects of age on the choice observations

Cluster	*Attribute level*	*Location*	*Coefficient*	*Std. Error*	*Significance (p-value)*
26-45	Green wallpaper	Patient room	1.65593**	.68576	.0157
46-65	Healing garden	Hallway	1.38685**	.56177	.0136
26-45	Wood wallpaper	Patient room	1.18703*	.65889	.0716
26-45	Nature poster	Patient room	1.08114*	.64233	.0923

4.6 Effects of scenario

As mentioned in the methodology, all respondents were appointed a scenario; either being *bed-bound* (scenario 1) or *mobile* (scenario 2). In the analysis, *bed-bound* patients were taken as reference. When testing the effects of scenario, the model became too singular to estimate. This suggests that the available data did not provide sufficient variation to distinguish differences in preferences of the two groups. Therefore, this study cannot conclude the influence of mobility of patients on the preferences regarding greenery integration.

4.7 Effects of risk of infection

The interviews with two infection prevention specialists gave insight into the restriction of greenery regarding infection control. The largest risk of greenery integration is the development of micro-organisms, which mostly root in the soil. The most important factors for the implementation of greenery are duration of contact, department and level of maintenance. Integrating greenery in patient rooms is currently (March, 2025) strictly prohibited, because of the long duration of contact between the patient and the plant. Moreover, the plant can function as a transferor of germs between patients using the room after each other. Patients are in some hospitals allowed to bring their own plant.

Implementing artificial greenery within patient rooms is also not preferred regarding infection control, since all plants would have to be cleaned thoroughly every time a patient is discharged from the hospital. Departments with patients who have a very low immune response, e.g. haematology and the intensive care, need to be protected even more regarding infection prevention. Bringing your own plant to these departments is also prohibited.

Implementing greenery in hallways and common rooms is allowed regarding infection prevention. However, care should be given to the maintenance of this greenery, mostly to prevent vermin.

Consequently, the infection prevention currently (March, 2025) restricts the implementation of plants within the patient room. The greenery interventions that would be implemented outside of the room (a nature view and greenery within the hallway of the department) or artistic depictions of greenery are possible considering the risk of infection.

4.8 Decision-making framework

The findings from the results of the SCE experiment and the interviews with inspection prevention specialists were combined into a decision-making framework. By following this framework, a series of different combinations of greenery interventions (measures) can be made. The interventions are presented in chronological order to let the decision-maker first consider the interventions that were preferred most by the patients. However, to allow for the inclusion of other decision-making factors, the framework gives the user the task to study the measure and decide for themselves if this measure should be implemented.

By including infection prevention regulations at various points, the framework ensures to include this barrier, while remaining future-proof by not assuming it will never be possible. Moreover, the combination of *wood wallpaper* and a *large plant* within patient rooms is restricted to incorporate the results from the interaction effects.

Figure 3 provides a schematic representation of the decision-making framework. This schematic representation shows the altered framework after the validation. A larger version of the framework can be found in Appendix A.

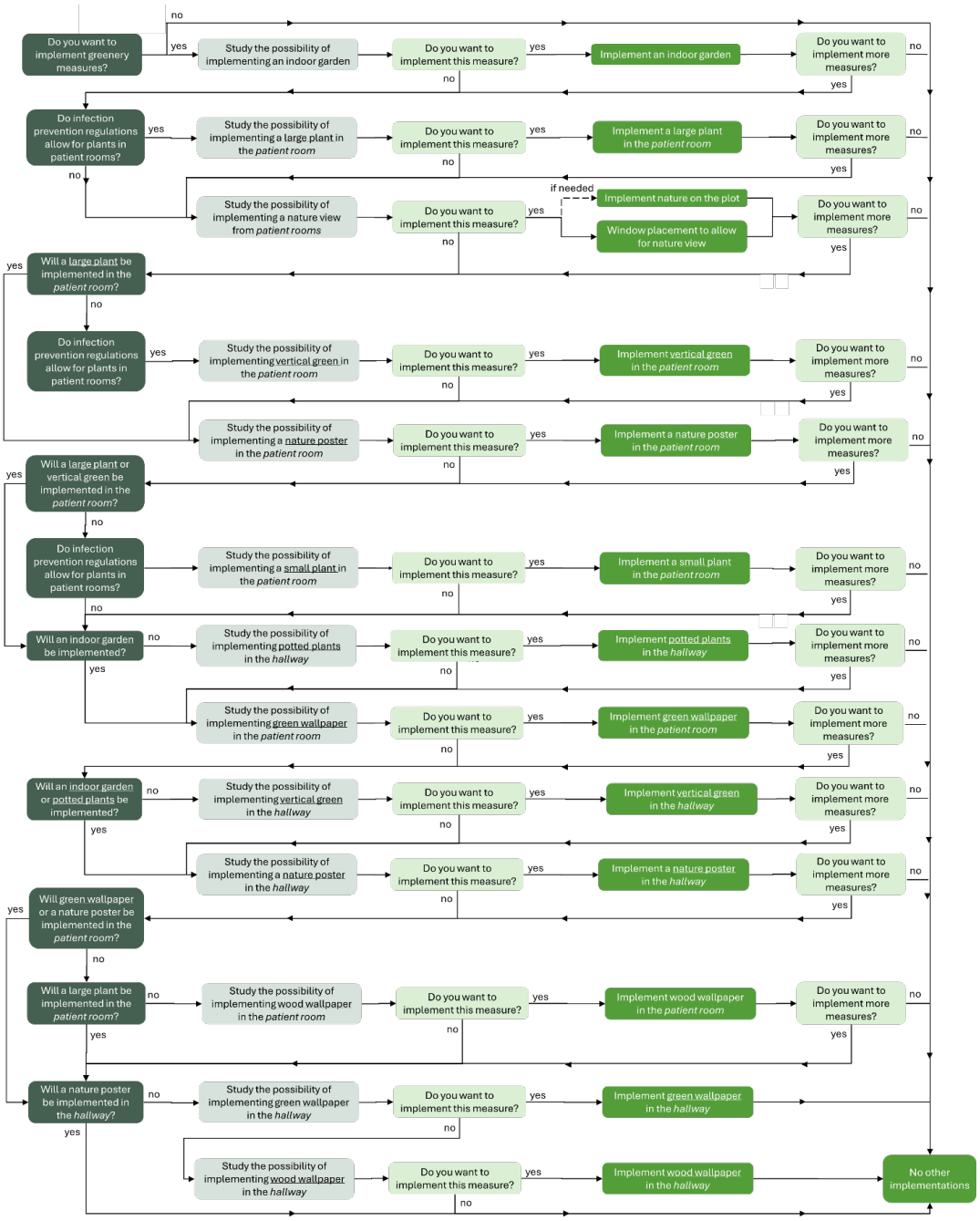

Figure 3: Schematic representation decision-making framework

The validation of a previous version of the framework showed that the consultants initially needed some time to become familiar with the framework. After repeated use, the consultants were able to successfully use the framework to follow the intended paths and draw the same conclusions. This confirmed the internal consistency of the framework. However, the feedback indicated that the framework was perceived as too complex to be easily applicable in practice. Several consultants noted an unfamiliarity with the use of flowcharts, making the framework less intuitive to use, which was also seen in the learning curve to use the framework as intended.

Therefore, the framework was translated into a Microsoft Excel tool, because this program is familiar to the consultants. The Microsoft Excel tool digitalized the framework, while presenting the same sequence of questions to keep the chronological order of greenery interventions as determined by the results of the stated choice experiment. This allowed for a more user-friendly way to determine which greenery interventions are suitable, while keeping the correlation with the research intact.

5. Discussion

In order to create patient-centred hospital designs, where greenery is integrated to stimulate holistic healthcare, hospital administration and healthcare real estate consultants need to know which greenery interventions are most desired by patients. Due to the vulnerable nature of this target group, conducting physical experiments involving patients is challenging. This is also reflected in the limited number of (clinical) studies on this topic and the frequent citation of Ulrich's experiment, which was conducted in 1984.

A methodological observation of this paper is that 49% of the respondents chose to answer additional choice sets. This shows the potential for this approach to generate more data for a SCE, without increasing respondent fatigue. Especially for vulnerable target groups, such as hospital patients, this approach provides a valuable alternative to more demanding experiments.

The findings of this study demonstrate that patients overall prefer hospitals where greenery is integrated, compared to environments with white walls and no nature, as all attribute levels showed a higher value compared to the reference scenario of white walls, a brick view and no nature. This supports existing literature (Van Iperen et al., 2023; Zaťovičová and Kubáňová, 2024; Zhu et al., 2024), that highlights the positive effects of integrating greenery in healthcare environments.

The strongest preference was observed for the presence of an indoor garden in the general ward, followed by a large plant in their patient room. Other strong contributing factors to patient value include having a nature view, a nature poster, vertical green or a small plant in the patient room. To date, no other studies have systematically compared patient preferences across different greenery interventions, making this finding a novel contribution to existing literature (Guidolin et al., 2024).

However, combining all greenery interventions was not always preferable. If a large plant is present in the patient room, white walls are preferred over a nature poster or wood wallpaper. If the presence of living greenery is not feasible, implementing a nature poster is preferred. This combination of greenery interventions and the preferences of patients was also not yet explored in literature. This paper contributes to this by gaining insights into which interventions reinforce positive outcomes when combined and which weaken the value regarding patient preferences. In this way, a "more is better" approach is discouraged, while carefully creating combinations of interventions is stimulated.

The analysis revealed that preferences varied by length of stay, though the differences were selective rather than universal. Compared to the reference group (short-term stays and day treatments), respondents of *medium stay* (2-5 days) valued green wallpaper and nature posters in the hallway more strongly, but nature posters and nature views less in patient rooms. Respondents of *long-term stay* (>5 days) or *short, but intensive stays* showed weaker preferences for healing gardens, but appreciated a large plant in the patient room more. These results suggest that patients with longer or more intensive stays prioritize direct greenery in their rooms, while those with shorter stays value greenery in shared spaces. This nuance extends previous research, which often either focused on patients of a single department or assumed uniform patient preferences across hospital departments (Guidolin et al., 2024).

No significant differences were found between male and female respondents, suggesting that gender is not a determining factor in preferences for greenery integration. This is consistent with previous research (Guidolin et al., 2024), indicating that this demographic factor is not a significant influencer of greenery preferences.

Compared to patients over 65 years old, those aged between 26 and 45 expressed stronger preferences for decorative indoor greenery (nature poster, wood wallpaper, green wallpaper) in the patient room. Since the respondents aged 18-25 only made up 0.4% of the sample size, and could not be reliably analysed, the results suggest that younger patients value decorative (greenery) elements more. Respondents aged 46-65 valued the healing garden more than the reference group (>65 years), indicating a greater appreciation of direct interaction with nature. This difference may be partly explained by the decline in average mobility as patients

age and therefore the ability of elderly patients to access healing gardens. These findings extend the limited literature on age-specific greenery preferences in healthcare settings (Guidolin et al., 2024; Zhu et al., 2024).

Regarding the state of mobility (bed-bound or mobile), the model could not be estimated due to singularity, reflecting insufficient variation to distinguish between bed-bound and mobile patients.

Infection prevention currently restricts the implementation of plants within the patient room, which were found to be popular among patients. This highlights a gap between patient preferences and the feasibility of real-life implementation of greenery interventions. However, implementing an indoor garden, nature view or a nature poster were attributes that are highly valued by patients and offer potential solutions if living nature is not allowed.

Overall, these findings provide guidance for patient-centred hospital designs, highlighting which greenery interventions are valued most by patients, indicating how preferences vary between patient groups and showing how combinations of greenery interventions can be made to create the most value for patients.

6. Limitations, practical implications and future research suggestions

By using the patient panel of the Albert Schweitzer hospital, a relatively large sample was obtained. However, since the members of the patient panel joined voluntarily, there is a self-selection bias present. This bias might also be strengthened by the panel member stop in 2023, resulting in no new members joining the panel after this date. The respondents consisted for 99% of people of a Dutch nationality and for 90% of people aged above 45 years old. This is not representative for the population of Dordrecht (the city in which the hospital is located) and the national numbers of hospital admissions in the Netherlands. As a result, the opinion of young (<45) and/or non-Dutch patients is underrepresented, limiting the generalizability of the findings.

Since a stated choice experiment was chosen as methodology, the research risks having a hypothetical context bias. The greenery interventions are shown in a hypothetical scenario, which may not fully reflect the complexity of real-life hospitals. Additionally, participants might have interpreted the attributes differently, affecting the consistency of the responses.

The hypothetical context bias also applies to the decision factors, since patients are asked to choose a hospital only based on certain factors in a hypothetical scenario.

Additionally, the respondents were assigned a hypothetical mobility scenario rather than asking their actual state of mobility for privacy reasons. This may have led some respondents to complete the survey without fully considering the assigned scenario, potentially limiting the ability to detect differences and resulting in the state of mobility not being analysed due to model singularity.

Despite these limitations, the findings offer evidence-based guidance for the design of patient-centred hospitals. By prioritizing indoor gardens, large plants in patient rooms and nature views, which were preferred most by patients, and by carefully selecting interventions to prevent combinations that decrease patient value.

Since a high level of taste heterogeneity was found among respondents, creating one type of room and hallway is unlikely to satisfy all patients equally. Short-term or day-treatment patients were found to benefit more from greenery in common areas, whereas patients of a longer stay value greenery directly placed in the patient room. Age preferences suggest that younger patients appreciate decorative indoor greenery more compared to elderly patients. Middle-aged patients appreciate healing gardens the most, a more experiencing type of greenery. When living plants are restricted due to infection control, alternatives like nature posters or nature views offer feasible solutions.

While this research showed patient preferences for greenery interventions, future research could be dedicated to conduct the same research among healthcare professionals. Studies indicate that the presence of natural elements in hospital settings reduces stress, enhances job satisfaction, improves alertness and positively influences the overall well-being among hospital staff (Bringslimark et al., 2009; Cooper-Marcus & Barnes, 1995; Pati et al., 2008; Sherman et al., 2005; Shukor et al., 2012; Van Iperen et al., 2023). Improved staff well-being will increase the level of care they can provide and therefore enhances patient recovery (CNV, 2023l Hinshaw & Atwood, 1984; Sherman et al., 2005; Shojonia et al., 2001; Shukor et al., 2012; Van Iperen et al., 2023). Additionally, the research can be conducted to visitors to investigate overlapping or contradicting preferences.

The research as presented here could also be conducted again among patients of a younger age (<45) and/or with another nationality to make the results more generalizable. Additionally, longitudinal studies could be conducted to examine whether greenery interventions influence patient preferences and well-being over time. A cost-benefit analysis could be applied to strengthen the application of the proposed decision-making framework.

7. Conclusion

Integrating greenery within healthcare environments is found to reduce stress, shorten recovery times and improve the perceived quality of the hospital design. This research contributes to a deeper understanding of how patients value specific greenery interventions within patient rooms and the general hallway of the ward. The results show that integrating greenery is highly valued by patients, especially through an indoor garden, large plants in the patient rooms, nature views and nature posters. Preferences vary across patient characteristics, such as length of stay and age, highlighting the importance of tailoring interventions.

Based on these preferences, the restrictions of infection prevention and the combinations, a decision-making framework was developed. Through this decision-making framework, the theory was translated into practice. By combining both quantitative data from the SCE and qualitative insights from the expert interviews and framework validation, the validity and applicability of the findings were strengthened.

Overall, the study contributes to the literature by providing evidence on patient-valued greenery interventions, their relative importance and possible combinations, and the heterogeneity of these preferences. These findings can be used in practice for the creation of evidence-based designs that focus on patient preferences, and for future research aimed at enhancing the patient experience within healthcare settings.

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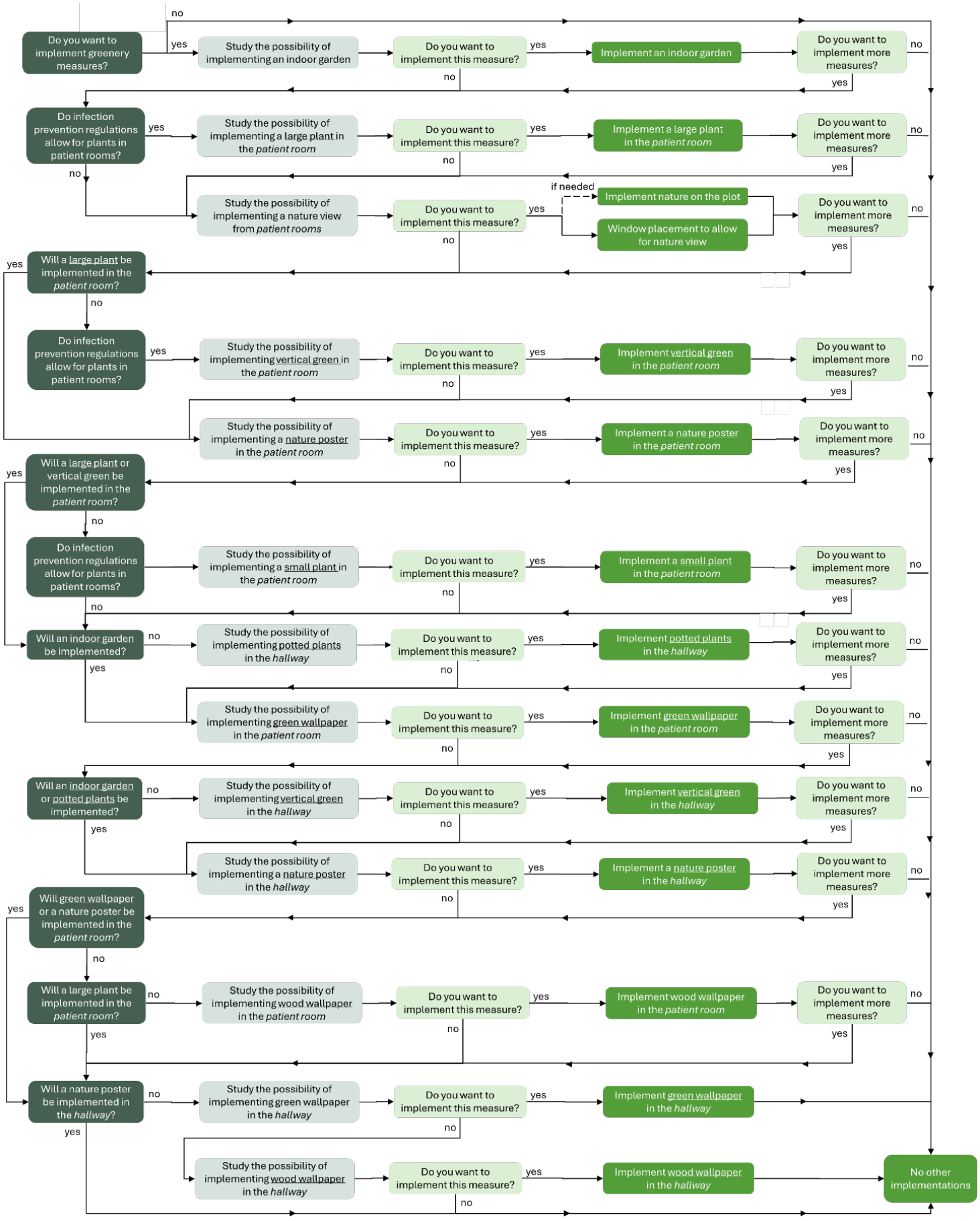
Appendix A: Schematic representation decision-making framework