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How to establish a well-functioning guidance system in a complex building structure

Modeling with multi-objective optimization

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Abstract

Wayfinding is a fundamental aspect of our daily lives, encompassing the activities involved in navigating from one place to another. In the context of architectural spaces, effective wayfinding is essential for ensuring a positive user experience and reducing frustration. This issue was brought to light by Solli Distriktpsykiatriske senter (DPS), as they observed difficulties faced by their patients in exiting the building after treatment sessions. Thereby introducing an interesting research question on how to establish a well-functioning guidance system within a complex building structure, with application to finding the way out.

In this thesis, an optimization approach has been taken to define the simplest path. Four multi-objective optimization methods are utilized to provide different perspectives on simplicity. The methods consider different weights and rankings of architectural features and the occupants' familiarity with the building, as these factors have been recognized as the most influential factors in daily wayfinding. Comparing the optimizations form the basis for concluding the most suitable method to define the simplest path. Interestingly, three out of four methods occasionally generate paths that contradict human instincts, which negatively affect orientation ability. This serves as the basis for making trade-offs between the methods. As a result, the weighted sum approach with equal weights is found to be the optimal method for defining the simplest path.

The findings of the optimization approach lay the foundation for establishing a well-functioning guidance system. When applicable, it is recommended to provide signage for the nearest optimal exit, using the simplest path, and the reception. This means that if the path to the reception, despite being longer, aligns with human instinct, it should be clearly indicated. Signage that confirms that the optimal exit route does not involve the main entrance will give the patients more confidence in following the designated path. This is important to ensure trust and reliability in the guidance system.

Furthermore, when utilizing the results, consistency in placement and design and the signs' readability are critical to establishing a comprehensive guidance system. It is recommended to incorporate a combination of directional and reassurance signs.

Keywords – wayfinding, multi-objective optimization, signage, guidance system, complex building, health facility

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1 Introduction

In our daily lives, we encounter numerous situations where navigating from one place to another becomes essential, i.e., the basic activities of wayfinding. From finding our way in unfamiliar cities to locating specific places within a building, wayfinding plays a crucial role in successfully reaching the desired destination. People use a combination of their human instincts, previous knowledge of the facility, and provided information to choose the optimal path. Wayfinding is increasingly difficult in an unfamiliar location or complex building, which can pose challenges that necessitate guidance for finding the optimal path.

Complex buildings present a unique set of challenges that can hinder our ability to navigate seamlessly. Structures such as hospitals and healthcare facilities often undergo expansion of the original facility and rehabilitations to accommodate evolving needs. Consequently, this stepwise construction results in intricate layouts, making it increasingly difficult for individuals to find their way without proper guidance. People may find themselves going astray, taking wrong turns, or getting lost altogether, leading to wasted time and frustration. We were introduced to the issue of wayfinding in daily life by Solli Distriktpsykiatriske senter (DPS), as they observed their patients having problems exiting the building after their treatment sessions. To address this problem, we seek to obtain an understanding of the patients' expected behavior and path choices when exiting the building.

Understanding the navigation within a complex building can be made easier by utilizing methodologies from emergency evacuation modeling, a field that has been extensively studied. Emergency evacuation is the process of quickly and safely exiting an area when an emergency occurs, and the priority is to minimize injuries and fatalities. To ensure safe and efficient evacuation, emergency evacuation modeling focuses on the optimization of routes with specific applications to find the shortest and quickest routes. By adapting the concept of optimization, we can apply similar principles to wayfinding in daily practice to minimize frustration and time wasted. In the case of wayfinding, our objectives are altered from exclusively finding the fastest exit routes to identifying the simplest and most user-friendly path to reach a desired destination.

To efficiently implement a system that assists in identifying the simplest route for wayfinding, it becomes crucial to define what constitutes simplicity in this context. Simplifying a route could involve minimizing the number of turns, reducing the complexity of the path, or providing clear and concise directions to guide individuals in line with human instincts. Through this research, we aim to explore and develop a methodology that quantifies simplicity in the context of wayfinding, enabling the creation of efficient route optimization strategies to be combined with an optimal guidance system.

The thesis is divided into nine chapters. In Chapter 1, the case problem of the thesis is presented in the introduction. Further, in Chapter 2, the object of the case study, Solli DPS, is presented. This includes insights into the daily activities, and the people flow at Solli DPS, an introduction to the building and its complexity, and the current guidance system at the center. Chapter 3 presents the relevant regulations regarding emergency evacuation and building exits. Following in Chapter 4, the relevant literature within the field is reviewed. Chapter 5 is the theory chapter. This section delves deeper into the theoretical framework that serves as the basis for our proposed model. In Chapter 6, the proposed model of the thesis is presented, first with an explanation of the chosen methods, followed by a discussion of the objectives included in the methods. Lastly, a presentation of the modeled network graph is presented. Chapter 7 presents the results of the optimization model for all different scenarios, with a subsequent analysis of the results. Based on the analysis, a discussion and recommendation for the guidance system are included in the last section of Chapter 7. Chapter 8 presents the limitations of the thesis and suggestions for further research. The conclusion can be found in Chapter 9, the final chapter.

2 Solli Distrikspsykiatriske senter

Solli DPS is a private, non-profit organization offering mental disorder treatments to people over the age of 18. The psychological disorders treated at the center are ADHD, anxiety, trauma, autism, bipolar disorders, depression, personality disorders, and eating disorders. The center can offer psychological and medical treatments, and accommodation. This list, while not exhaustive, provides a good overview of the daily activities at Solli DPS.

The following patient statistics were provided to us by Solli DPS directly. Table 2.1 shows the percentage of patients in the different age groups. On average, 180 patients pass through the building daily. Scheduled patients have, on average, eight visits to the center. In addition, there are twenty bed posts, with a 90 % fill rate, i.e., on average, 18 patients with residence at Solli DPS. Also, there are 130 employees at the center.

Table 2.1: Patient statistics for the percentage of patients in the different age groups.

Age range	**Percentage of patients**
18 - 30 years	49%
31 - 50 years	31%
51 - 64 years	14%
65+ years	5%

Considering the nature of the activities conducted at Solli DPS, increased frustration and uncertainty in wayfinding within the building proves to be disadvantageous. However, the center, similar to many other health facilities, has undergone expansions from the original facility, increasing the building's complexity. This expansion has resulted in a structure consisting of four interconnected buildings and one stand-alone building. The overview of the building can be viewed in Figure 2.1

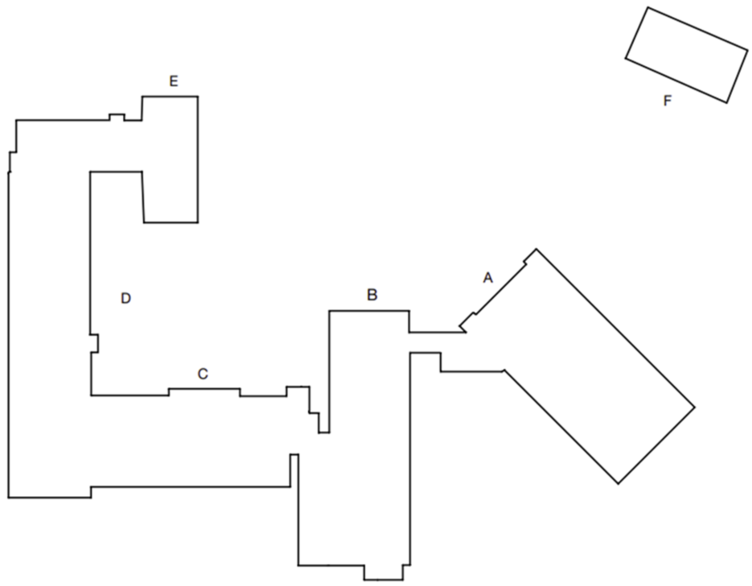

Figure 2.1: Building layout

The different sections of the building were constructed during different time periods. The original facility, Building E, was built in 1955. Further, the building was extended when Building D was built in 1962. Building B was initially constructed in 1972, and Building F was built in 1998. In 2008 Buildings B and D were interconnected as Building C was built. Lastly, Building A was built in 2015, and Building B was rehabilitated simultaneously.

The center has a total of six levels. The layout of each floor was provided to us by the building drawings we received from Solli DPS, which are included in Appendix A1, and inspected through physical visits. Due to the different building periods, each of the sections of the building has, to a varying extent, different floor plans and characteristics. The building has different rooms that serve distinct purposes, such as offices and meeting rooms, a fitness facility and gym, a cafeteria, and an arts and crafts room. While many of these rooms are available to patients, some are strictly for the employees, such as the kitchen, employees' break rooms, and storage spaces carrying electrical panels. Furthermore, there are some intermediate floors in the connections of Building D and Building E, and Building B and Building C. The building has 23 exit points spread over the three lowest floors, as the building is located on a slope, giving different exit levels. Nine exits are used daily, while the remaining is only used during an emergency evacuation.

The intricate nature of the building at Solli DPS poses challenges to effective navigation. To ensure successful navigation, the provision of information along the paths is essential. This structured information is referred to as the guidance system. However, designing an effective and coherent guidance system is difficult due to the complexity of the building. Notably, there's a necessity for different information in different situations, e.g., daily wayfinding versus emergency evacuation. Solli DPS currently has a guidance system that includes both signage for daily wayfinding and emergency evacuation.

First, the guidance system adapted for wayfinding in daily situations focuses on finding specific rooms in the building, e.g., the cafeteria or gym. This guidance system could be held to some criticism. Visual references are provided in Figure 2.2 for illustrative purposes:

Figure 2.2: Illustrations of signs for daily navigation at Solli DPS.

The designs of the signs are not the best, as they are heavily packed with information, both in the form of text and arrows, and the size of the symbols is relatively small. This reduces readability. Moreover, the information on the signs is outdated and inaccurate as they do not correctly reflect the current layout of the building or the actual usage of the rooms. This can lead people to make a wrongful turn and waste additional time. In addition, the signs are mainly just present in Buildings A and B, indicating a lack of consistency in the placement of the signs.

Second, the evacuation guidance system at Solli DPS incorporates clear emergency exit signs. The designs are in line with established recommendations from Wong and Lo (2007) and Galea et al. (2014). Numerous emergency exit signs are strategically positioned throughout the building, ensuring evacuees can access multiple evacuation routes from any location within the facility. The redundancy provided by the multiple evacuation routes is advantageous in the event of route blockages caused by hazards; however, this can also introduce confusion as occupants may lack clarity regarding the quickest path. Complementing the signs, certain walls within the building display floor plans illustrating the exit routes. However, the utilization of these exit route plans within the building is considered to be less intuitive as an information source within a guidance system(Helbing et al., 2005).

3 Relevant regulations

The Norwegian law and regulations “Byggteknisk forskrift (TEK17)” (Direktoratet for byggkvalitet, 2017) govern building construction, and this is the bare minimum needed for buildings to be erected lawfully. It consists of 18 chapters, where Chapter 11 offers information about emergency requirements and fire safety precautions. Regulations are in place to ensure that structures comply with health, safety, and environmental standards. The following paragraphs of Chapter 11 directly regulate the exit and escape planning part of constructions and, thereby, are of interest to this research. However, it is generally necessary to read all the regulations to comprehend the requirements fully.

The general guidelines for fire safety precaution, §11-1, state the requirements to satisfy safety measures, provide guidance on the capacity to save all occupants’ evacuating, and enable effective and undemanding efforts.

In §11-8, we can find a description of the concept of fire cells; according to the regulations, a building is sectioned into fire cells in reference to its layout, e.g., the kitchen, a stair, and all patient rooms at hospitals and health facilities must be defined as fire cells. The sectioning shall be done appropriately without risk of life and hazard. The main criteria for fire cells are to have a minimum of one safe exit, and the large fire cells with a capacity of many occupants must have a sufficient number of exits and a minimum of two.

The specific regulations on route guidelines and rescue prerequisites are given in §11-11. According to the regulations, buildings are required to be designed to enable quick and efficient evacuation, taking precautions for individuals with disabilities. The escape path must be simple, quick, and efficient to ensure safe evacuation during an emergency. The signs, symbols, and text to direct occupants must be legible and recognizable under all conditions, such as fire and smoke.

4 Literature review

The purpose of this chapter is to conduct an extensive review of the existing research literature within the relevant fields of research in reference to this thesis. This literature review covers various essential areas of research; wayfinding, evacuation modeling, psychological features, and signage both in a day-to-day situation and evacuation.

Firstly, we will explore previous research within the field of wayfinding as it directly relates to our research topic at hand. By examining previous studies in this area, we can gain insights into the various aspects of wayfinding and different wayfinding strategies. Understanding the existing body of knowledge within wayfinding is crucial for our research, as it allows us to build upon and contribute to the current understanding of this field.

Secondly, we will elaborate on the findings within the field of evacuation modeling, which forms the foundation for our proposed modeling approach. Evacuation modeling draws upon the basics of traffic assignment models. These methodologies have been further developed in the field of route optimization during emergency evacuation. The work on evacuation modeling provides us with insights and methodologies to enhance our understanding of route optimization and its application to daily wayfinding.

Another crucial aspect we review is the influence of psychological features, i.e., how human behavior can influence the choices one makes while navigating. There has been conducted research on psychological features and their effect on emergency evacuation. By examining the psychological aspects that affect decision-making, information processing, and response behavior during emergency situations, we can gain valuable insights into objectives that may also affect daily wayfinding at Solli DPS.

Lastly, it is important to recognize that wayfinding and emergency evacuation rely on signage as a crucial element. Therefore, we will review the findings related to signage, both for daily wayfinding and evacuation. By examining the existing research on sign design, placement, and effectiveness, we can identify best practices and principles that can be applied to developing a well-functioning guidance system.

4.1 Wayfinding

Farr et al. (2012) defined wayfinding as the process of using cues to find one's way to a destination, whether in a familiar or unfamiliar setting. In comparison, Symonds (2017) categorizes wayfinding as a cognitive, social, and corporeal process that involves locating, following, or discovering a route through and to a given space. Montello and Sas (2006) points out that successful wayfinding requires accurate, precise, complete, and up-to-date information to ensure that the destination meets the needs of the occupants and is reached efficiently.

Furthermore, according to Kitchin (1994) and Prestopnik and Roskos-Ewoldsen (2000), wayfinding ability can be influenced by two main categories of factors: external factors, which relate to the physical characteristics of the environment or building, and internal factors, which relates to individual characteristics such as familiarity with the surroundings and the navigation strategies employed within a specific environment. Hölscher et al. (2006) propose three wayfinding strategies for complex buildings. (1) The central point strategy is where individuals stick to well-known parts of the building, such as the main entry hall and main connection corridors, even if this requires considerable detours. (2) The direction strategy involves selecting routes that lead directly toward the horizontal position of the destination, irrespective of level changes. (3) The floor strategy involves first finding the way to the floor of the destination, irrespective of the horizontal position of the destination.

4.2 Evacuation modeling

To fully understand evacuation modeling, it's essential to understand traffic assignment models. This is because current evacuation planning and management models are primarily built on traffic assignment models, namely the user equilibrium (UE) and system optimal (SO) approaches (Bayram, 2016). Wardrop (1952) introduced the concept of equilibrium, which defines that the journey times in all the routes actually used are equal and less than those experienced by a single vehicle on any unused route. Bayram (2016) accentuate the limitation of the UE model due to its assumption that the evacuees have full information about the traffic conditions on the road network. To address this issue, Jahn et al. (2005) have researched the SO approach while still accommodating individual needs by imposing additional constraints to ensure drivers are assigned to "acceptable" paths only. The shortest path problem was first introduced by Dijkstra in 1956, and the problem has found practical applications in evacuation modeling, where it is used to determine both the safest and quickest evacuation route (Deng et al., 2012; Samah et al., 2015).

Boxill and Yu (2000) and Li et al. (2019) states that evacuation models can be classified into macroscopic, microscopic, and mesoscopic models. Macroscopic models focus on the crowd as a whole, while microscopic models continuously or discreetly predict each individual state. Mesoscopic models combine macro and micro models. Shin et al. (2019) have pointed out that macroscopic models in optimization problems treat evacuees as a homogeneous group, while microscopic models focus on describing the interactions between individual evacuees during egress.

Further, evacuation management can be approached through deterministic or stochastic models, with the main difference being that stochastic models incorporate randomness and uncertainty in the modeling. Most of the literature proposing new ideas or methods to support evacuation planning and management decisions relies on deterministic models that adopt a single hazard scenario, such as the worst-case or most probable scenario (Bayram, 2016).

4.3 Psychological features

Understanding evacuees' route choices and behavior is necessary to find the optimal evacuation route or pathway in a building. When optimizing evacuation models, various psychological perspectives can be included. Lu et al. (2014) present the most studied psychological features in the literature: familiarity, herding, nervousness, and guidance. Further, they have categorized the features into two levels: tactical (including familiarity, guidance, and herding) and operational (including nervousness); this is also researched by Bode and Codling (2013), which stated that the operational level is the level of individual behavior, and tactical is the way they choose to go.

Prestopnik and Roskos-Ewoldsen (2000) expressed that to be familiar means that occupants have increased knowledge concerning objects or locations in the environment. Then Lu et al. (2014) said that with increased familiarity in a building, occupants prefer, on a tactical level, to use familiar routes, even if the route differs from the guided route or does not lead to the nearest exit.

The psychological feature of herding is emphasized as a problem in the evacuation by Helbing et al. (2005) and Pan et al. (2007). Lu et al. (2014) confirmed this and further elaborated that herding behavior causes people to concentrate on the exits with the most evacuees. It makes the evacuees tend to follow the largest group in sight, other occupants' behaviors and choices, or use exits they are familiar with to reduce decision time (D'Orazio et al., 2014).

Lu et al. (2014) points out that evacuees can become nervous when they are close to fire and smoke and when there are blockages at a passage, which can lead to impatience and pushy behavior. When occupants become nervous, it can intensify their herding behavior and make people depend more on familiarity.

Finally, Lu et al. (2014) pointed out that guidance affects evacuees' route selection by giving them route information, and their route selection depends on their trust in the information. Helbing et al. (2005) has also stated that trust is essential to increase orientation ability in a way that corresponds to human instinct and psychology, using optical and acoustic guidance systems rather than confusing plans of escape routes.

4.4 Signage

For optimal and effective wayfinding, it is important to use signage that guides occupants in the right direction and design a system according to human instinct. Farr et al. (2012) have stated that signs provide a one-way form of communication and convey facts and information about environments without ambiguity. Signs perform various functions, such as directing, informing, controlling, and identifying, and fall under three basic types: directional, identification, and reassurance signs. All information signs should be placed in well-lit places at critical points, such as nodes and decision points. They should be noticeable, unobstructed, legible, and oriented to the actual environment. Additionally, location, clustering, consistency, and light were confirmed by Symonds (2017) as critical when designing maps for signs. Symonds (2017) and Rodrigues et al. (2019) also claims that the design process must consider factors such as color, size, language, symbols, and other elements. Passini (1996) has pointed out the importance of consistency in the form and location of wayfinding and signage information; designers can significantly reduce symptoms of overload when taking this into consideration.

4.5 Evacuation signage

Passini (1996) stated that wayfinding can become more challenging during stressful conditions, such as emergency evacuation, usually explained by inadequate signage. According to Chu and Yeh (2012) studies on evacuation guidance have focused on the relationship between the design of evacuation signs, e.g., shape, text, pattern, and height, and occupants' ability to see them. Further, they categorized evacuation into two major categories: fixed guidance, which is pre-determined and does not change over time, and adaptive guidance, that is changing according to the current situation of congestion or hazard. However, the quality of a guidance system is usually measured by its sign coverage and evacuation route distance. Zhang et al. (2017) stated that a successful evacuation signage system can indicate a fast and efficient evacuation route by simplifying the complexity of a building, compared to a poor signage system which may lead to more casualties.

5 Theory

This chapter presents the technical premises and support for the proposed model. The theories are elaborated here to give an insight into the terminology and mathematical formulations used in the model.

5.1 Network flow theory

A network flow problem aims to move some entity from one point to another in an underlying network and do so as efficiently as possible (Ahuja et al., 1993, p.1). Network flow theory is defined using graphs, where a graph is an abstract mathematical object containing sets of nodes and edges (Magzhan and Jani, 2013). Nodes are placed where occupants stay and can move to, and the edges connect pairs of nodes (Magzhan and Jani, 2013). The network's nodes and edges may have associated numerical values such as length, capacity, cost, and/or supply and demand (Ahuja et al., 1993, p.24).

5.2 Shortest distance

The shortest path problem is the problem of finding the shortest path or route from a starting point to the destination (Magzhan and Jani, 2013). The topic is highly researched, and different algorithms exist to solve the shortest path problem. The most popular conventional shortest path algorithms are the Dijkstra algorithm, Floyd-Warshall algorithm, and Bellman-Ford algorithm (Magzhan and Jani, 2013).

The main difference between the three algorithms is that Dijkstra's algorithm only works with non-negative edge values. In contrast, both the Floyd-Warshall algorithm and the Bellman-Ford algorithm allow for negative edge values. The computational simplicity of the three algorithms is acceptable in terms of overall performance for solving the shortest path problem. However, Dijkstra's algorithm is typically faster when applicable, i.e., when the graph has only non-negative values (Magzhan and Jani, 2013). Since we are dealing with distances that are always positive numbers, Dijkstra's algorithm is applicable.

5.3 Weighted sum approach

For a set of $f_i(\bar{x})$ objective functions, where $\bar{x} = [x_1, x_2, \ldots, x_n]$ is the vector of decision variables, the weighted sum approach consists of adding all the objective functions together to one joint function using different weighting coefficients for each one of them (Coello, 1999). This means that a multi-objective optimization problem is transformed into a scalar optimization problem of the form (Coello, 1999):

$$Minimize \sum_{i=1}^{k} w_i f_i(\bar{x}) \tag{5.1}$$

, where $w_i \geq 0$ are the weighting coefficients representing the relative importance of the objectives. It is usually assumed that (Coello, 1999):

$$\sum_{i=1}^{k} w_i = 1 \tag{5.2}$$

The main strengths of this method are its efficiency (Coello, 1999) and its simplicity and ease of use (Gunantara, 2018). One of the weaknesses is the difficulty in determining the appropriate weights when there's not enough information about the problem (Coello, 1999). Therefore, there will be a bias in finding a trade-off solution. Secondly, a problem would appear if the plural problem that is optimized is not convex (Gunantara, 2018).

5.4 Lexicographic ordering

The lexicographic ordering is a multi-objective optimization method where the designer ranks the objective functions in order of importance (Coello, 1999). The objective functions are a set, $f_i(\bar{x})$, where $\bar{x} = [x_1, x_2, \ldots, x_n]$ is the vector of decision variables. The optimal solution is obtained by minimizing (or maximizing) the objective functions, starting with the highest-ranked objective and proceeding according to the assigned order of importance (Coello, 1999).

The optimization problem given the lexicographic ordering is formulated as

$$Minimize\ f_1(\bar{x}) \tag{5.3}$$

Subject to

$$g_j(\bar{x}) \leq 0; \qquad j = 1, 2, \ldots, m \tag{5.4}$$

and its solution $\bar{x_1}^*$ and $f_1^* = (\bar{x_1}^*)$ is obtained (Coello, 1999). Then the second problem is formulated as

$$Minimize\ f_2(\bar{x}) \tag{5.5}$$

Subject to

$$g_j(\bar{x}) \leq 0; \qquad j = 1, 2, \ldots, m \tag{5.6}$$

$$f_1(\bar{x}) = f_1^* \tag{5.7}$$

and its solution x_2^* and $f_2^* = f_2(x_2^*)$ is obtained.

To generalize, by denoting the ordered objective functions with k, where k equals the number of objectives, the problem can be formulated as

$$Minimize\ f_i(\bar{x}) \tag{5.8}$$

Subject to

$$g_j(\bar{x}) \leq 0; \quad j = 1, 2, \ldots, m \tag{5.9}$$

$$f_l(\bar{x}) = f_l^*, \quad l = 1, 2, \ldots, i-1 \tag{5.10}$$

The solution obtained at the end, i.e., x_k^*, is taken as the desired solution x^* of the entire multi-objective optimization problem.

The main strength of the lexicographic approach is its simplicity. However, the main weakness is that it will tend to favor certain objectives when many are present in the problem because of the randomness involved in the process (Coello, 1999).

6 Propsed model

In the following chapter, the proposed model of the thesis is presented. Firstly, an explanation of why the given optimization methods were chosen for this thesis is specified. Secondly, a discussion regarding the relevant objectives is conducted to provide insight into the thought process for setting the weighted values and ranked orders in the multi-objective optimization methods. Lastly, the network graph of the thesis is explained in depth, which is built based on the information given in Chapter 2, the relevant theoretical framework presented in Chapter 5, and the discussions on the methods and objectives in this chapter. The proposed model is built and runs using the R programing language.

6.1 Optimization methods

The optimization methods implemented in this thesis are the shortest distance, weighted sum approach, and lexicographic ordering. The following arguments explain why the given models are applicable in a case focusing on wayfinding in daily practice and why they are appropriate for comparison.

The primary focus of the optimization in this thesis is to optimize the patient's wayfinding during daily navigation, i.e., finding the simplest path. The simplicity of a path is affected by human behavior, psychological features, and path complexity, all of which have been identified in previous research. These factors must be implemented into the objective function, giving multiple objectives to optimize simultaneously, thereby inducing the need for multi-objective optimization. Considering this, we have chosen to implement both the weighted sum approach and the lexicographic ordering method. Both methods have the strength of efficiency and simplicity, making them easy to implement even with data uncertainty. Also, they both have the ability to take into account all the above-mentioned factors impacting the optimal route choices. Both methods are included as they are dependent on parameters set by the designer but have different implementation methods and, as a result, may yield different optimal solutions. The opportunity to see how the various implementation methods impact the optimal path is desirable as the parameters are set under uncertainty. Valuable insights can be gained from the optimization results on where to guide individuals in a comprehensive manner while considering human factors.

In addition, from previous research, it is clear that the optimal route choice when applied to emergency evacuation is highly focused on the shortest path and/or the shortest evacuation time. As mentioned earlier, the guidance system for emergency evacuation at Solli DPS consists of multiple path options in both signage and evacuation plans, i.e., not only the shortest or quickest route. However, we have confirmed that the shortest path found using the Dijkstra algorithm is a part of the existing emergency guidance system for all relevant start nodes. Therefore, the shortest distance method is also included in this model to compare the potential impact a guidance system optimized for a day-to-day situation may have on evacuation.

6.2 Weighted values and ranked ordering

When implementing the weighted sum approach and the lexicographic ordering methods, some measures must be taken for the estimated weighted values and the ranked ordering. Therefore, the following discussion is dedicated to how to set the weighted values and ranked ordering of the multiple objectives implemented in the model. As these are not given measures and must be set by the designer, the discussion is focused on how to set these in reference to each other.

6.2.1 Psychological features

From the literature, we find that the psychological features, i.e., the internal factors, that may impact human behavior in a wayfinding situation are familiarity, herding, nervousness, and guidance.

In previous research, the focus on herding has been on its harmful and potentially deadly effect in buildings with large crowds in open areas, such as football stadiums and nightclubs (Helbing et al., 2005). These are not characteristics of the building of Solli DPS. Furthermore, it is worth noting that the people flow at Solli DPS on an average day is relatively low when considering the size of the building and the recommended fire safety guidelines regarding fire cells outlined in TEK17 §11-8. Based on this information, it seems unlikely that Solli DPS will experience extensive overcrowding or bottlenecks during an emergency evacuation, and as a result, this is even less relevant when it comes to daily navigation. Thus, herding is excluded.

Initially, we were interested in whether the patients' psychological disorders impact the day-to-day wayfinding. However, the impact of the patient's mental state is such a broad research topic that it has been excluded from the scope of our thesis. Therefore, the mental state of the patients is not implemented in the proposed model, including, amongst other states, the nervousness of the occupants. This is further supported by a conversation with a psychiatrist at the center, who affirms that the patients are functioning similarly to others in their daily lives.

In a wayfinding situation, when in doubt, the occupants have a greater probability of choosing a familiar path than an unfamiliar path (Lu et al., 2014). This indicates that taking familiar paths is more probable as it is a natural human instinct, which increases the orientation ability (Helbing et al., 2005). Therefore, it is understood as particularly interesting to study the impact of path choices at Solli DPS, as familiarity with the building will vary depending on the number of visits. This raises an interesting question regarding the implementation of patients' individuality, which can be incorporated into the model by considering various scenarios involving groups of occupants. In addition, the first strategy of Hölscher et al. (2006), the central point strategy, argues for building a model that focuses on paths sticking to as many familiar parts of the building as possible, for instance, the main entrance. Therefore, familiarity as an objective is built into the model as a factor based on the patient groups' assumed familiarity with the exits.

The other psychological feature highlighted in wayfinding and evacuation literature is the importance of guidance. As stated, inadequate signage usually explains wayfinding difficulties (Passini, 1996). Therefore, the signs used for wayfinding must be adequate so that the occupants trust the guidance (Lu et al., 2014). To ensure this, it is essential to establish a system that corresponds to human instincts and psychology, and have knowledge of whom the signs are aimed at, guiding and adjusting the information accordingly (Symonds, 2017). This again substantiates the implementation of multiple occupant scenarios.

6.2.2 Wayfinding difficulties

The complex layout of Solli DPS presents challenges in terms of wayfinding. Passini (1996) supports this notion by highlighting how architectural shortcomings often contribute to difficulties in navigation. Further, Passini (1996) states that signs indicating architectural features, such as the indication of entrances, exits, horizontal paths, stairs, and elevators, are architectural inadequacies and signage for such elements is difficult to convey. However, these architectural wayfinding cues are crucial at Solli DPS to ensure successful navigation. Therefore, the model considers the following architectural features, which are the external factors affecting the wayfinding within the center: stairs, elevators, passing through doors, and making turns.

Initially, it is obvious that physically passing through a closed door is more difficult than walking through an open corridor. Additionally, using stairs and elevators and making turns is more time-consuming than walking straight forward.

The literature states that the number of decision points, i.e., the number of turns, increases the difficulty (Passini, 1996). The least-angle strategy first described the reduced complexity of routes with the least angles, which focuses on navigation in an outdoor environment (Hölscher et al., 2006). In later research, the strategy has been further developed for indoor navigation as the direction strategy (Hölscher et al., 2006). The direction strategy arguments for building a model focusing on paths making as few turns as possible, increasing the probability of an occupant's successful wayfinding, and highlighting the importance of minimizing the number of turns in the optimal path.

Using stairs or elevators is required at Solli DPS as it is a multi-level building. In a trade-off between stairs and elevators, the minimization of elevators is ranked higher as elevators should be prioritized for individuals with disabilities. Additionally, when exiting a building, not moving upwards but down towards the ground floor aligns with human instincts. As the building is located on a slope and has intermediate floors, occupants may take paths moving both up and down stairs. Therefore, the number of stairs should be minimized.

Considering the discussion above, it is crucial to include familiarity, guidance, and path difficulty in the proposed model. These factors play a critical role on path simplicity. The literature does not conclude which objectives should be weighed or ranked the highest. However, the familiarity feature is one of the most dependent factors impacting occupants' route choices. Guiding architectural features are difficult, and such signs are challenging to convey. Making turns contributes to increased route complexity, reducing the occupant's probability of successfully reaching their desired destination. All these factors should be implemented in the proposed model. The objectives are implemented, maximizing familiarity and minimizing the architectural features, i.e., the number of stairs, the number of elevators, the number of turns, and the number of doors that the path must pass through. The findings are not one-sided, therefore a weighted sum approach with equal weights is included as the baseline. Additionally, based on the discussion, another weighted sum approach with higher weights for familiarity and turns, and two lexicographic ordering methods are included. The weighted values and ranked orders are presented in the following two tables:

Table 6.1: Weighted sum approach methods.

	Equal weights	**Higher weights for familiarity and turns**
$w_{1:\text{length}}$	0.1667	0.1
$w_{2:\text{stairs}}$	0.1667	0.1
$w_{3:\text{elevators}}$	0.1667	0.1
$w_{4:\text{turns}}$	0.1667	0.3
$w_{5:\text{doors}}$	0.1667	0.1
$w_{6:\text{familiarity}}$	0.1667	0.3
w_i	1	1

Table 6.2: Lexicographic ordering methods.

Lexicographic ordering with familiarity ranked highest	**Lexicographic ordering with simplicity ranked highest**
$f_{\text{familiarity}}$	f_{turns}
f_{turns}	f_{elevator}
f_{elevator}	f_{stairs}
f_{stairs}	f_{doors}
f_{doors}	$f_{\text{familiarity}}$
f_{length}	f_{length}

6.3 The network graph

The data on the patient statistics and the building drawings presented in Chapter 2 gives the foundation for building the network graph. The nodes and edges have been structured over the building drawings, which can be thoroughly analyzed in the Network Layout Drawings in Appendix A2. Additionally, parameters and scenarios in line with the discussion above are implemented to complete the model. The network is visualized in Figure 6.1

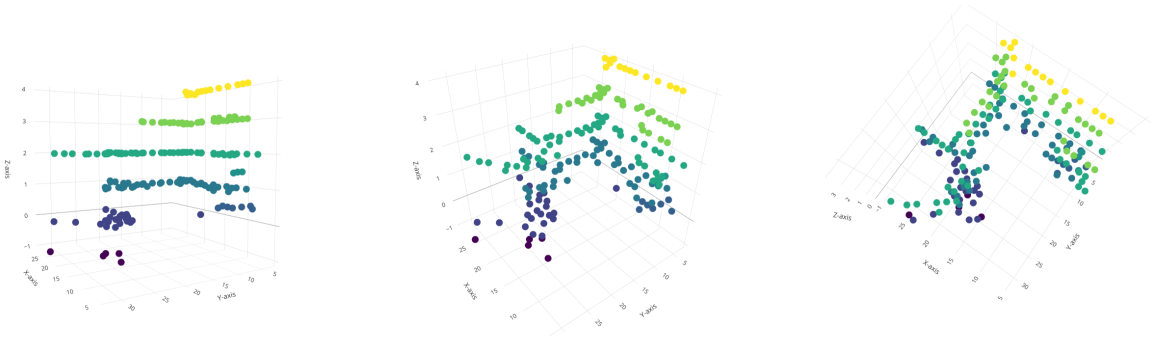

Figure 6.1: 3D-plot of the building network.

In the following table, the sets of the network are presented:

Table 6.3: The sets for the network.

Symbols	**Description**
N	Collection of nodes, representing a logical space.
E	Collection of edges between nodes (e.g., a corridor, stairway, or elevator), which can also be expressed as (u, v), where $u, v \in N$.
G	$G = (N, E)$, an undirected graph consisting of the nodes and edges representing the building layout.
$source\_nodes$	The network source nodes indicating a natural occupant location, $source\_nodes \in N$.
$sink\_nodes$	The sink nodes of the network, the building exits, $sink\_nodes \in N$.
$s.nr$	The occupant scenarios (1:3).

The set N represents the set of nodes in the network, giving the different locations in the building layout. There are 179 nodes in the network. E is the set of edges connecting the network graph nodes, which can be a corridor, stairway, or elevator. The edges can be defined as the set of nodes (u, v), where $u, v \in N$. There are 203 edges in the network graph.

The placement of occupants is based on the understanding of what is considered natural places for the occupants to be located, which is based on the patient statistics from Solli DPS. The natural places for the occupants to be located give the foundation for what is defined as the source nodes of the network. The $source\_nodes$ is a subset of N and is defined as the nodes at which the occupants may be located. There are 85 source nodes in the network.

By examining the building drawings and the current exit routes, we can determine the locations of all exits. This includes exits that are regularly used and those that are only used in emergency situations. The $sink\_nodes$ is a subset of N and is defined as the nodes to which the occupants can exit. There are, in total, 23 possible exits in the building layout, but only nine are used in daily practice. The day-to-day exits are defined as a subset of the $sink\_nodes$, which is 1 when an exit is used in daily practice otherwise 0, i.e., $familiar\_exits$, and the emergency exits are the 0's of this subset.

The $s.nr$ set states which of the given occupant scenarios the model is optimized in regard to. The different scenario numbers give a specific occupant group, as follows; 1: first visit, 2: multiple visits, and 3: resident.

The parameters of the network are presented in Table 6.4:

Table 6.4: The parameters of the network.

Symbols	Description
$l_{u,v}$	The length of an edge (u, v).
$s_{u,v}$	Binary parameter, 1 if edge (u, v) is a stairway, otherwise 0.
$e_{u,v}$	Binary parameter, 1 if edge (u, v) is an elevator, otherwise 0.
$t_{u,v}$	Binary parameter, 1 if edge (u, v) includes making a turn, otherwise 0.
$d_{u,v}$	Binary parameter, 1 if edge (u, v) includes passing through a door, otherwise 0.
$f^k_{s.nr}$	The probability of route k being chosen, based on the familiarity of the route exit, given the occupant scenario $s.nr$.
w_i	The weight of objective i in the multi-objective function for the weighted sum approach.

Parameter $l_{u,v}$ is the physical length of an edge (u, v) in meters. The measures are taken on converted PDF files in Auto-CAD. The converter is not 100% precise, so the measures are somewhat off from the real-world measures. However, the dimensions are correct in reference to each other, and will, therefore, still give the proper indications and results.

Parameters $s_{u,v}$, $e_{u,v}$, $t_{u,v}$, and $d_{u,v}$ are all binary variables equal to 1 if the edge (u, v) is a stairway, an elevator, makes a turn, or passes through a door, respectively, otherwise 0.

$f^k_{s.nr}$ is the probability of exit route k being selected, based on the familiarity of the exit in the respective routes. The definition is based on the findings of Lu et al. (2014), which define the probability of a route being selected, concerning the psychological factor familiarity as:

$$Pr(Select\ k|t^1_f, \ldots, t^m_f) = \frac{t^k_f}{\sum_i t^i_f} \tag{6.1}$$

, where a group of occupants' trust in route k is denoted by t^k_f, which ranges from 0 to 1 ("0" represents the case with no knowledge, and "1" represents full knowledge). The familiarity and trust in the different exits will vary based on the occupant's familiarity with the building, which will differ based on the number of visits a patient has had to the center. First-time visitors and visitors that have been to the building multiple times will have different probabilities for a given route. The residents are understood to have greater familiarity with the exits than the scheduled patients. The probabilities are therefore computed concerning a given occupant scenario. The defined set $s.nr$ gives the different scenarios available, and the trust in the nine day-to-day exits is set as follows for the three occupant scenarios:

$$\text{for } s.nr = 1 : t_f^k = (0.4, 0.4, 0.4, 1, 0.2, 0.2, 0.2, 0.4, 0.4) \tag{6.2}$$

$$\text{for } s.nr = 2 : t_f^k = (0.8, 0.8, 0.8, 1, 0.6, 0.6, 0.6, 0.8, 0.8) \tag{6.3}$$

$$\text{for } s.nr = 3 : t_f^k = (1, 1, 1, 1, 1, 1, 1, 1, 1) \tag{6.4}$$

The level of trust among occupants of a path is determined by the visibility of the exit the path leads to. If the exit is easily visible, occupants are assumed to have a higher level of trust in the path. The exit with full familiarity for all scenarios is the main entrance. The exits with the next level of familiarity in the first two scenarios, i.e., 0.4 and 0.8, are the exits that are easy to see walking through the building, and the ones on the last level, i.e., 0.2 and 0.6, are the ones that are not as easy to see.

The w_i parameter gives the weighted value of each objective i in the multi-objective optimization problem under the weighted sum approach, as given in Table 6.1.

7 Results and discussion

The implementation of multiple methods in the optimization process arises from recognizing that simplicity is a multifaceted concept. However, to improve the user experience of navigating complex buildings, it's important to find one optimal solution for the simplest path. We cannot have multiple optimal solutions, i.e., signage for the way out in multiple directions simultaneously. Therefore, the primary objective of this thesis is to determine the true simplest path by comparing the optimal solutions generated by the four multi-objective methods within the proposed model. This analysis will serve as the basis for developing a comprehensive guidance system considering all relevant factors.

Therefore, in this chapter, we will first present the results obtained from the optimization methods, comparing the optimal paths and drawing conclusions regarding the identification of the simplest path. After analyzing the results of the proposed model, we will present our recommendations ensuring the implementation of a comprehensive guidance system. This will involve incorporating insights from the optimization findings and relevant literature on signage and decision points.

7.1 Optimization findings and path comparison

Running the proposed model in R, we obtain four optimal path solutions for the simplest path for all three occupant scenarios using the multi-objective optimization methods. To compare the results of the optimizations, we will floor-wise and section-wise, go through the different path choices for all possible start nodes at Solli DPS. This will provide insights into how the distinct characteristics of each method influence the selection of the optimal path. Following the path comparison, we will provide a general conclusion on which method(s) is understood to be applicable for optimizing the simplest path in a complex building. The optimal paths generated by the method(s) are subsequently compared to the shortest distance method from the proposed model to assess whether the simplest path can be regarded as having a significant impact on emergency evacuation.

7.1.1 Comparison of the multi-objective optimization findings

THE 4thFLOOR

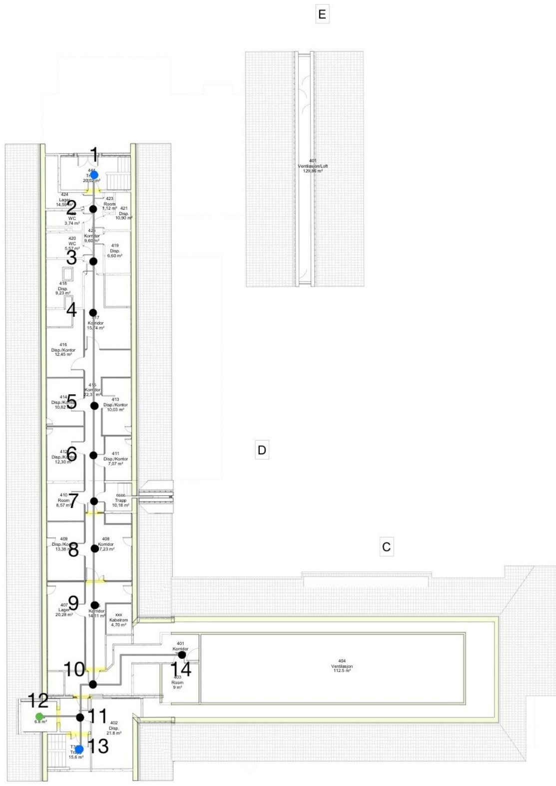

Figure 7.1: Network layout of the 4th floor.

For start node 3 all the way through to start node 8 (3:8), all method returns the use of stairway 1 as the optimal path, except for the lexicographic optimization method with familiarity ranked the highest for first-time and multiple-time visitors, i.e., the scheduled patients. The optimal path, in this case, is to move towards stairway 13, down towards the first floor, and out of the main entrance. For start node 11, using the stairway 13 is always the optimal choice. Below, Figure 7.2 presents a visualization of the optimal familiar path in green, and the optimal simplest path in blue, starting from node 3.

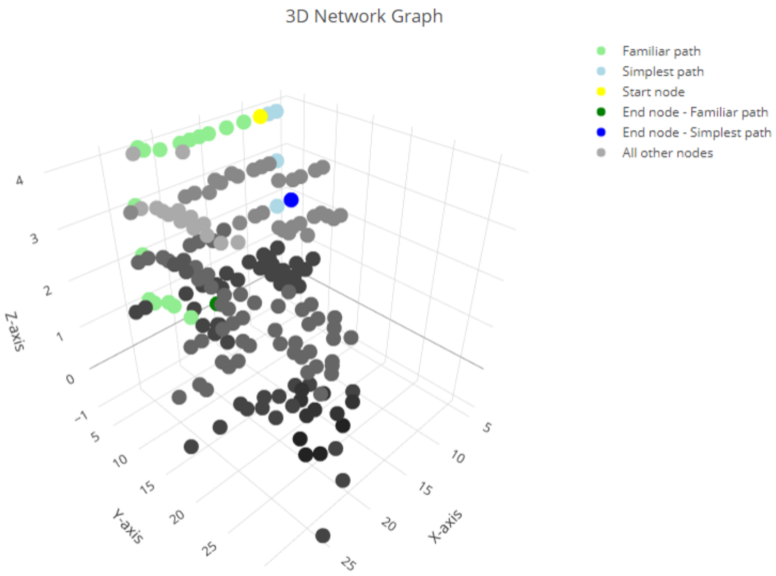

Figure 7.2: 3D plot of the network graph with the optimal simplest and familiar paths from start node 3.

For scheduled patients, when using the lexicographic ordering method with familiarity ranked highest, the main entrance will always be selected as the optimal exit point. This is because the main entrance has the highest familiarity. Arguably, as the highest-ranked objective has a clear maximum or minimum value, this strict optimization approach can be seen as limiting. In Figure 7.2, the familiar path identified as optimal is more challenging due to multiple closed doors. This increases the risk of making wrong turns during the navigation. It demonstrates how the choice of the highest-ranked objective in the lexicographic method can significantly impact what is considered the optimal path. However, it's important to note that the intention of this method is to analyze the influence of solely knowing the direction towards the main entrance on the selection of routes.

THE 3rd & 2nd FLOOR

Building C

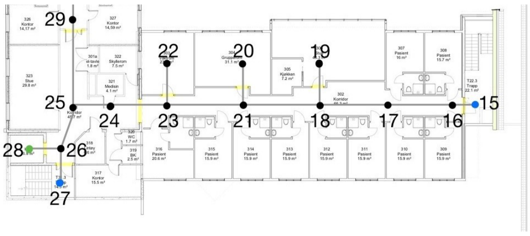

Figure 7.3: Network layout Building C on the 3rd floor.

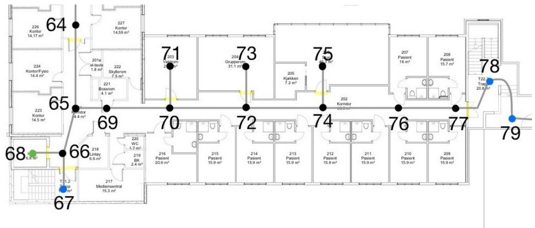

Figure 7.4: Network layout Building C on the 2nd floor.

It is important to note that the sections of Building C on floors two and three are only accessible to the residents. Therefore, the optimal solution for wayfinding in Building C for these two floors does not apply to the scheduled patients. All methods return the same optimal paths for the relevant start nodes, i.e., 16:23 and 70:77. The residents shall walk down the stairway 15/78 to the main entrance for nodes 16:19 and 74:77, and down the stairway at node 27/67 for start nodes 20:23 and 70:73.

Building D

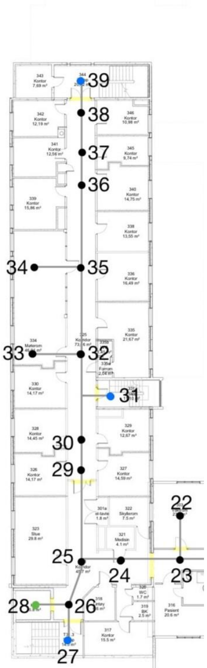

Figure 7.5: Network layout Building D on the 3rd floor.

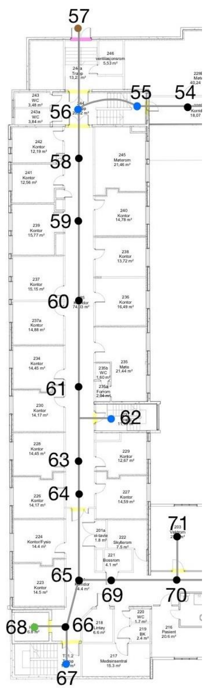

Figure 7.6: Network layout Building D on the 2nd floor.

For start nodes 25:38 on the third floor in Building D, all optimization methods return exit 57 as the optimal exit point, except for lexicographic ordering with familiarity rank the highest which return the main entrance, as explained before. The same applies to nodes 55:65 on the second floor. The simplest and familiar path for Building D on these two levels is presented in Figure 7.7 belove.

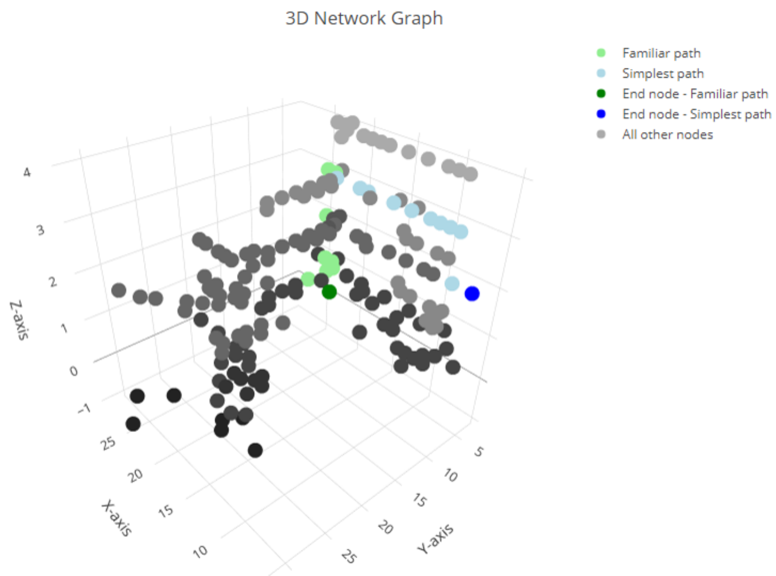

Figure 7.7: 3D plot of the network graph with the optimal simplest and familiar paths from start node 25, which is the same for start node 65 one floor down.

Building E

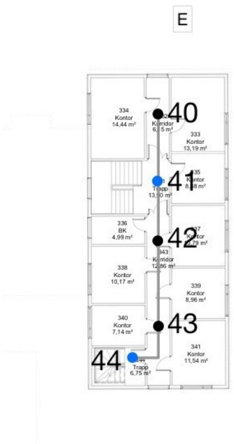

Figure 7.8: Network layout Building E on the 3rd floor.

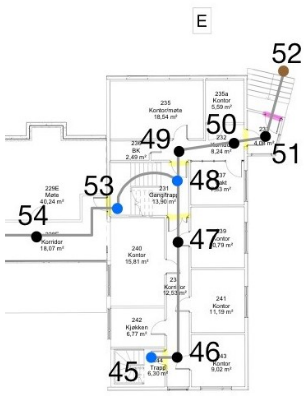

Figure 7.9: Network layout Building E on the 2nd floor.

All methods return the optimal exit point in Building E on the second and third floor as exit node 52, with two exceptions. The lexicographic ordering with familiarity ranked highest for scheduled patients and the weighted sum approach with higher weights for familiarity and turns for first-time visitors return the main entrance as the optimal exit point.

We have already discussed the issues associated with using lexicographic ordering, where familiarity is ranked the highest. However, the weighted sum approach with higher weights for familiarity and turns is included to provide a somewhat more nuanced perspective on the objectives. It acknowledges the higher significance of familiarity and turns as found in existing literature, but also takes into account the other objectives at hand. Despite these considerations, the method, in this case, produces a path that conflicts with logic. The method identifies the main entrance as the optimal choice, even though it makes the path more difficult as it passes through the intermediate floors, illustrated in Figure 7.10.

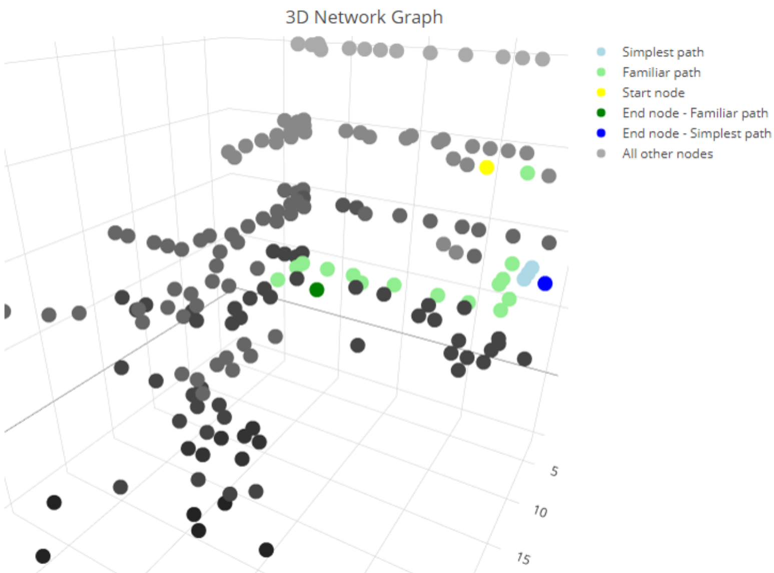

Figure 7.10: 3D plot of the network graph with the optimal simplest and familiar paths from start node 42.

Buildings A and B

Buildings A and B are only located on the second floor, and not present on the third floor.

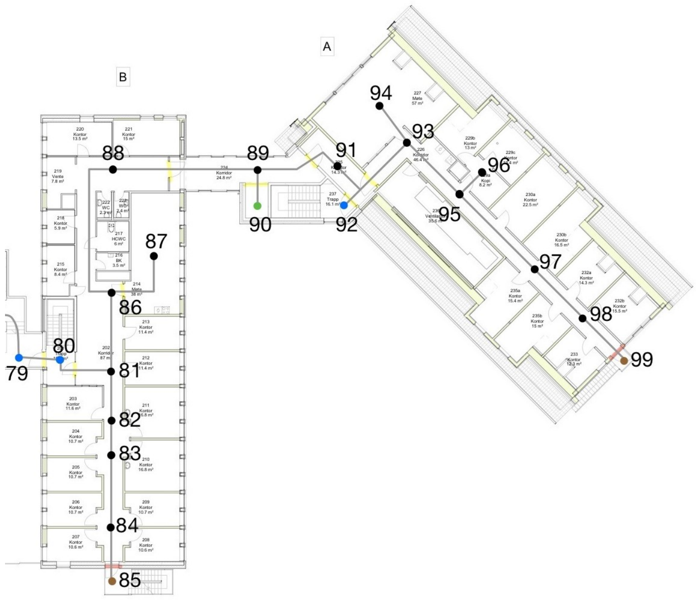

Figure 7.11: Network layout Buildings A and B on the 2nd floor.

For start nodes 81:87 in Building B, all multi-objective optimization methods for the scheduled patients return the optimal exit point to be the main entrance. In that case, the occupants are required to walk through the doors to stairway 78 and descend these stairs to reach the first floor.

For start node 88, however, there are some differences in the optimal paths chosen. The structure is visualized in Figure 7.12.

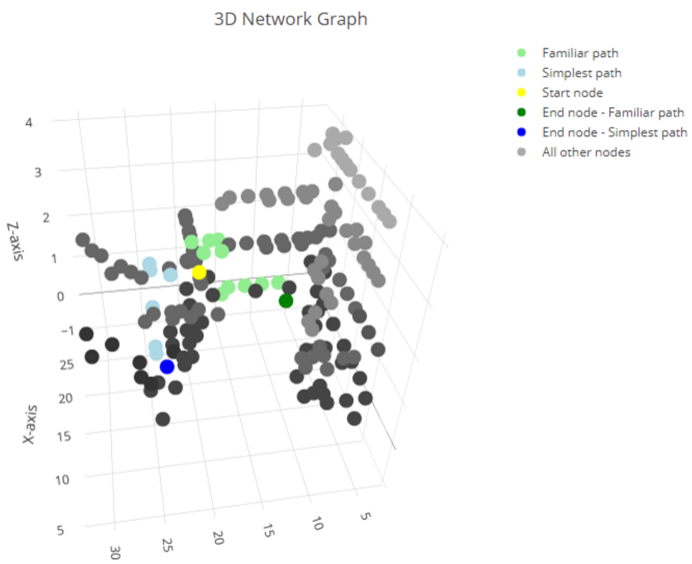

Figure 7.12: 3D plot of the network graph with the optimal simplest and familiar paths from start node 88.

The lexicographic ordering with familiarity ranked the highest still return the main entrance as the optimal exit point for scheduled patients. The same is found for the weighted sum approach with higher weights for familiarity and turns for first-time visitors. For all other occupant scenarios and methods, the optimal path is to use the stairs in Building A to move two floors down and walk out at exit point 168 at the 0^{th} floor. For start nodes 91:98 in Building A, the optimal paths are the same as for start node 88.

THE 1^{st} FLOOR

Buildings A and B

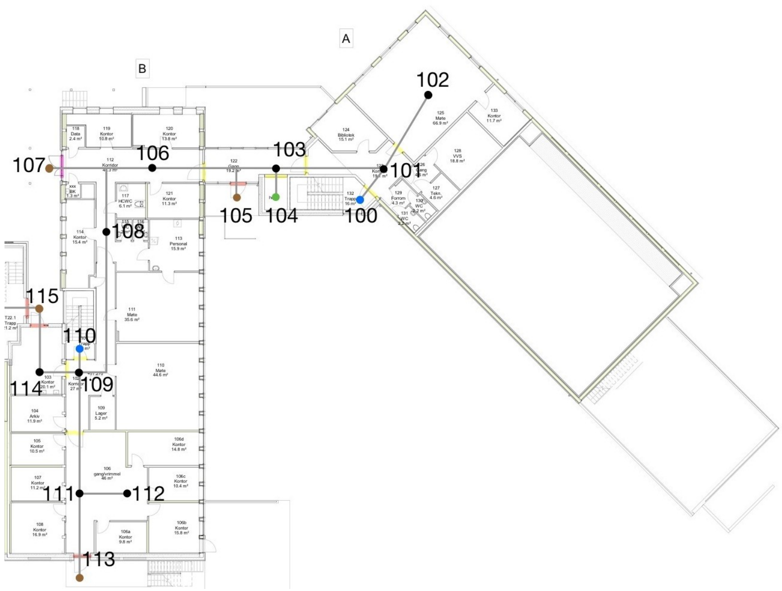

Figure 7.13: Network layout Buildings A and B on the 1^{st} floor.

For all start nodes on the first floor in Buildings A and B, the optimal path ends with node 107. This again, except for lexicographic ordering with familiarity ranked the highest, which by default for scheduled patients finds a path to the main entrance, not considering any other factors. On this floor, the buildings are not interconnected, and reaching the main entrance would entail either walking partial outside or ascending to the upper floor before descending again, which goes against human instinct.

Building C

Figure 7.14: Network layout Building C on the 1st floor.

Regardless of the occupant scenario, all methods return the main entrance, i.e., node 123, as the optimal exit point for start nodes 116:122.

Building D

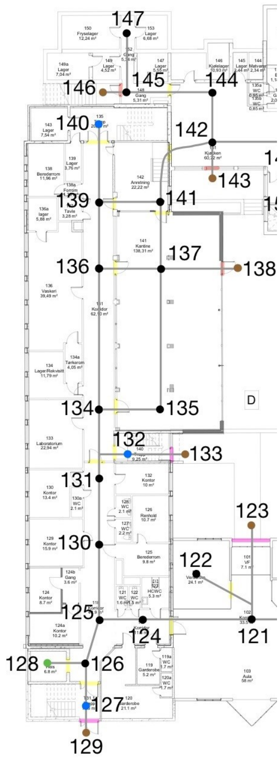

Figure 7.15: Network layout Building D on the 1st floor.

For the start nodes 130:139, all methods return the optimal exit point for scheduled patients as the main entrance.

However, the methods yield different optimal paths for the residents. The weighted sum approach with equal weights returns the optimal exit point as point 129. The three other methods find the path ending at node 57 on the second floor as the optimal path. This path includes ascending the stairway at node 140, thereby walking upwards in the process of exiting the building, again conflicting with human instincts. The reason for the selection of this path is due to its minimal number of turns. This is chosen by the lexicographic ordering method with simplicity ranked the highest as this method minimizes turns as the initial objective. This, again, highlights the drawbacks of such a rigid optimization approach when the highest-ranked objective has a clear maximum or minimum value. Simplicity does not solely refer to the number of turns. Similarly, the lexicographic ordering method, with familiarity ranked the highest, also suggests this path for residents since the familiarity objective remains the same for all exit points in this occupant scenario. Furthermore, when applying the weighted sum approach with higher weights for familiarity and turns, the same path is chosen, further illustrating how this method also occasionally contradicts human intuition and logic.

Building E

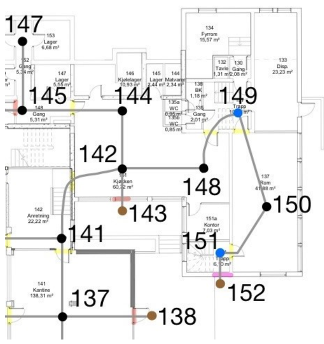

Figure 7.16: Network layout Building E on the 1st floor.

The only start node in Building E on the first floor is node 150. Nodes 142:148 are only available to the employees, as this is the kitchen area. All methods for all occupant groups return exit node 152 as the optimal exit point, except for the lexicographic ordering method, with familiarity ranked the highest for scheduled patients which again return the not so reasonable optimal solution of exiting through the main entrance.

THE 0^{th} FLOOR

Buildings A and B

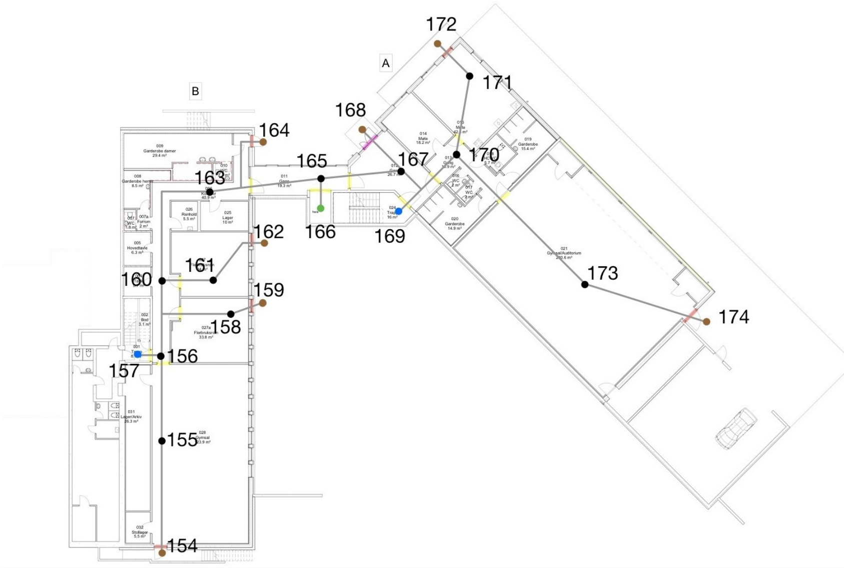

Figure 7.17: Network layout Buildings A and B on the 0^{th} floor.

For occupants located on floor zero in Buildings A and B, the optimal path for all methods returns exit point 168 as the optimum. The only exception is again the lexicographic ordering with familiarity ranked the highest for scheduled patients, and the weighted sum approach with the highest weights for familiarity and turns for first-time visitors.

THE -1^{st} FLOOR

Building A

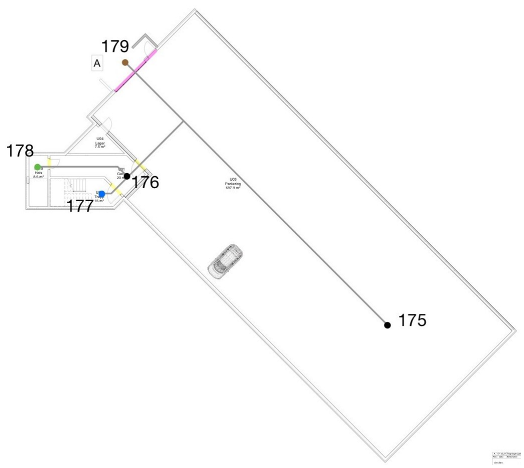

Figure 7.18: Network layout Building A on the -1^{st} floor.

The underground garage in Building A has one natural exit point through the garage doors to node 179. All methods return this solution, except lexicographic ordering with familiarity ranked the highest for scheduled patients, which again is not reasonable.

Building F

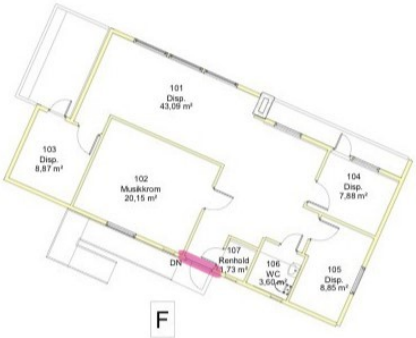

Figure 7.19: Network layout Building F on the 0th floor.

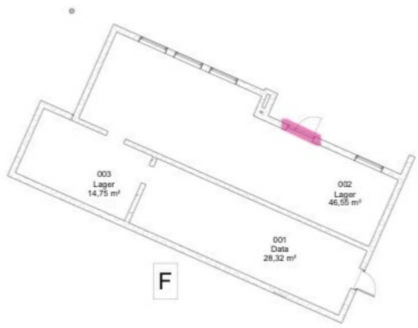

Figure 7.20: Network layout Building F on the -1st floor.

Building F is present on the 0th and -1st floors. However, the building only has one exit point on each floor, thereby giving only one possible exit path. This is not further examined.

7.1.2 General findings

The main findings from the optimizations are that some of the methods tend to prioritize a single objective too strictly. For the lexicographic methods, there are instances where certain paths stand out as the optimal choice only for that method. The paths are often excessively long, with increased difficulty and/or conflict with human instincts. This indicates that the methods can be considered too rigid as the other objectives than familiarity or the least turns are neglected. Similarly, despite utilizing the weighted sum approach to achieve a more nuanced optimization, the optimal paths occasionally conflicted with human instincts.

Considering the goal of improving user experience and finding the optimal simplest path when exiting a complex building, the weighted sum approach with equal weights proves to be the most suitable. This method considers multiple objectives without returning illogical paths. As a result, it can serve as a foundation for establishing a comprehensive guidance system, effectively supporting daily navigation.

Furthermore, in the process of determining who to signage for, it is important to differentiate between patient groups, i.e., the different occupant scenarios in the proposed model. Priority should be given to signage for those who are least familiar, such as the scheduled patients, as they may require more guidance. In comparison, the residents are assumed to be already familiar with all exits used in daily practice. In addition, scheduled patients are the dominant group in reference to patient numbers. Overall, we also often find the optimal paths for the scheduled patients and residents using the weighted sum approach with equal weight to be coinciding. Therefore, the residents can choose to follow the signage implemented when in doubt or rely solely on their higher degree of familiarity to navigate. By adopting this approach, the guidance system will be optimized to accommodate the needs of the most vulnerable groups in reference to wayfinding.

Therefore, the recommendation is to utilize the weighted sum approach with equal weights to determine the optimal paths for scheduled patients and use this as the basis for the signage of the way out of the building. However, the familiarity feature is emphasized in the literature as highly influential on path choices and not considering this factor may be critical in inducing frustration among the patients. The method that focuses solely on familiarity (the lexicographic ordering method with familiarity ranked highest), in line with the central point strategy, often yields different optimal paths, particularly when optimizing for scheduled patients, as it consistently identifies the main entrance as the optimal exit point. Establishing a guidance system for scheduled patients that considers both simplicity and familiarity will bring significant benefits and has the potential to create a more comprehensive and intuitive guidance system. Nonetheless, it is not feasible to provide signage for the way out based on multiple methods. However, implementing signage for the main entrance or reception can serve as a foundation for incorporating familiarity into the guidance system based on the optimal paths from the lexicographic ordering method when applicable. Indeed, this approach of simultaneous signage for both the reception and the way out helps to build trust in the guidance system. By providing signage confirming that the optimal exit route is not through the main entrance, patients will feel more confident in following the indicated path. This reassurance strengthens their trust in the guidance system's accuracy and reliability, enhancing their overall experience and ensuring that they are directed to the appropriate exit.

7.1.3 Comparison with the shortest distance method

As pointed out earlier in the thesis, it is crucial to ensure that the optimal paths for daily wayfinding do not significantly affect the emergency evacuation flow. Therefore, we will now briefly compare the optimal paths generated by the weighted sum approach with equal weights to those obtained through the shortest distance method.

Initially, an important discretion is the fact that the optimal paths using the weighted sum approach with equal weights are all options in the emergency evacuation at Solli DPS due to the multiple path signage strategy. Furthermore, in most cases, the optimal paths identified through the equal weights method either lead directly to the designated emergency exits or pass by them. This is considered satisfactory given that occupants follow the emergency exit signs during evacuation.

However, there are a few instances where the simplest path diverges from the optimal emergency evacuation exit. This occurs, for instance, at start nodes 7:8 in Building D on the fourth floor, shown in Figure 7.1. The simplest path descends stairway 1 and exits at that end of the building, while the emergency evacuation exit is at the other end of the building using stairway 13. Nevertheless, the difference in path length is minimal. Furthermore, the regular path is more straightforward, which suggests that it may also be the safest route during an emergency evacuation. By following the familiar path, occupants can minimize the risk of getting lost, thus enhancing their chances of safe evacuation.

Overall, the optimal path derived from the weighted sum approach with equal weights is not anticipated to have a critically negative impact on the emergency evacuation flow. This assumes good emergency evacuation signage and that evacuees follow these signs when an emergency occurs.

7.2 Recommendations for the guidance system

As mentioned previously, the signage at Solli DPS suffers from poor construction and a lack of consistency. This presents a significant opportunity for improvement in both sign design and their placement throughout the entire building.

To achieve a higher degree of successful exiting at Solli DPS, the following section provides suggestions on sign design and occupant guidance through the building. These recommendations are based on the optimization findings. Firstly, we will present suggestions for the sign design for the guidance system for daily wayfinding. Secondly, a presentation on how to implement the different signs at critical decision points at Solli DPS is given. Lastly, we will provide a brief analysis of the emergency evacuation signage.

Today, Solli DPS relies on a static guidance system. However, considering the complexity of the building, a dynamic signage system might be more appropriate. Nevertheless, implementing such a system can be challenging and costly. Fortunately, with a well-designed wayfinding strategy and carefully crafted signs, a static guidance system can still effectively facilitate successful wayfinding. Therefore, the following analysis will focus on the implementation of a static, optical guidance system aimed at enhancing navigation and improving the overall user experience.

7.2.1 Sign design

As stated, we can define the design of signs as the information part of the wayfinding problem. Signage serves the purpose of providing occupants with adequate and accurate information to guide them, reducing frustration, and minimizing wasted time. To tackle the wayfinding challenges at Solli DPS, there would be a necessity for a combination of sign types. Directional signs, which are already in place, are important for giving the occupants directions. Further, we recommend the implementation of reassurance signs to address the need for support. These signs can increase trust and reliability, assuring occupants that they are heading the right way.

During the design process, it is crucial to consider the specific occupants we are designing for, which in this case are the three occupant scenarios implemented in the proposed model, however with a focus on the scheduled patients. While different individuals may require different signs, the signs themselves will be standardized for everyone. The primary focus is on helping the scheduled patients find their way out of the building.

The visual part is a primary factor in this design process; colors, symbols, size, and language will be considered. First, the colors of the signs should be consistent, and all signs should have the same color code. The color code can be set in line with Solli DPS's new logo, which has the colors blue, white, and grey. Using the same colors is in line with consistency in design and also gives the potential for working with contrasts, i.e., a light background against dark letters and reverse, which is emphasized in the literature. Another optical part of the signs is the use of symbols; as of today, text and arrows are being used. Arrows and words are good tools for directing people, but they must be appropriately designed so the occupants can understand them, i.e., proper sizing and usage to ensure readability. It is recommended to point the arrows away from the text. Lastly, the signs at Solli DPS are in Norwegian, and this is covering the needs at the center today. However, a relevant discussion might be whether to also include English.

The information on the signs should be well thought out because inadequate signs are a source of confusion and failed wayfinding. According to the recommendation from Rodrigues et al. (2019), the information should be sorted through a hierarchy of importance and logic. The list of destinations should be at most five. The information must be clustered if there are more than five destinations on a sign. The primary information should be in bold, while the rest should be in regular letters. Also, the information on the signs must be up to date and precise. Figure 2.2 on page 5, the signs at Solli DPS today, show signage as "Til andre avdelinger" (To other departments) and "Grupperom" (Group rooms). This is really general and cannot be defined as precise and may therefore be a source of confusion. Both these terms should either be excluded or redefined to give a more precise description. The evaluation of whether they should be included or not should be based on who uses these rooms and whether these occupants are the same as the ones that use the guidance system.

We have created an example of a redesigned directional sign, based on the first and second signs presented in Figure 2.2. We have made the draft with consideration to the above-mentioned design recommendations. The sign draft is illustrated in Figure 7.21.

Figure 7.21: Draft of the layout on an improved directional sign at Solli DPS.

Further in Figure 2.2 (c), the third sign presented is placed in a stairway that currently functions as a directional sign. However, our recommendation is to change it into a reassurance sign. When standing in a stairway, the key decision for occupants is whether to proceed to the floor they have reached or continue moving up or down. The current directional sign illustrates this using arrows. We propose a simplified approach for enhanced readability. Instead of arrows giving upward and downward directions, we suggest using a bold font to indicate the current floor. Occupants will then naturally interpret the information above and below the bold font as referring to the floor one level up and down, respectively. These types of reassurance signs are recommended for implementation in all stairways, and Figure 7.22 provides an illustration of such a sign.

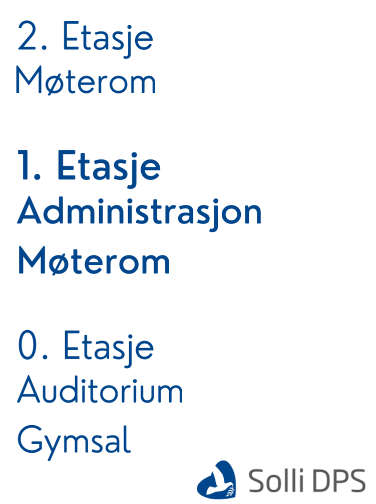

Figure 7.22: Draft of the layout of a reassurance sign at Solli DPS, an improvement of a previous directional sign.

Based on the optimization findings and the objective of this thesis, it is recommended that all reassurance signs should indicate on which floor the nearest exit is and on which floor the reception area is. In addition, the directional signs should be included to provide guidance on the direction to the nearest exit, and the directions to the reception, when the reception is not the nearest exit. This is to increase trust in the guidance system. However, the signage for the reception should only be included if the occupants are not led on a path that contradicts their human instincts, as it would in Buildings A, B, and E at Solli DPS in reference to the optimization findings. Implementing the directional and reassurance signs at Solli DPS will contribute to creating a well-functioning interaction between the architecture and signage.

7.2.2 Decision points

A decision point is a crucial location where occupants require specific information to make the right choice regarding their direction (Passini, 1996). The placement of information at these points is crucial and should provide occupants with the necessary guidance, typically in the form of a directional sign.

As previously mentioned, it is recommended to have reassurance signs at all stairways on each floor. Providing clear guidance on the next steps to take after exiting the stairway in line with the optimal path is essential in reducing wrong turns and minimizing wasted time, i.e., directional signs. These directional signs are also important at intersections or when the occupants get to the end of a corridor and need to make a 90-degree turn to ensure successful exiting. An example of such a decision point at Solli DPS are at the interception between Buildings C and D as shown in Figure 7.23, with a proposed directional sign at this point as shown in Figure 7.24 .

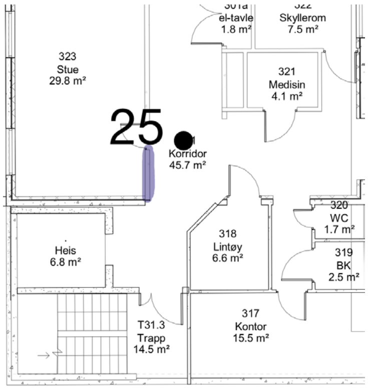

Figure 7.23: Identification map with a marking of the wall for the location of the directional sign at node 25.

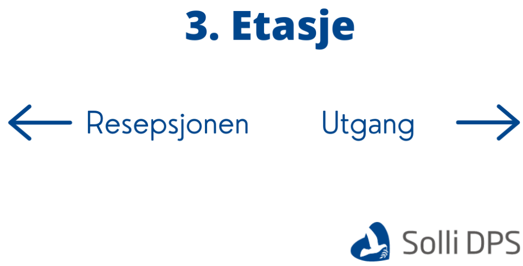

Figure 7.24: The directional sign for the wall of node 25.

Additionally, we have identified the need for additional directional information when the optimal path includes passing through closed doors. These doors should be clearly marked, for example, with the phrase "Til Resepsjonen" (To the Reception), giving direction using words, not arrows. To use arrows in this example could give a lower degree of clarification, as there is not one unified way to pointing through a door. At Solli DPS such a directional sign is needed at the interception between Buildings B and C, as the optimal path to the reception is through the stairway on node 80, illustrated in Figure 7.25. With the associated directional sign illustrated in Figure 7.26.

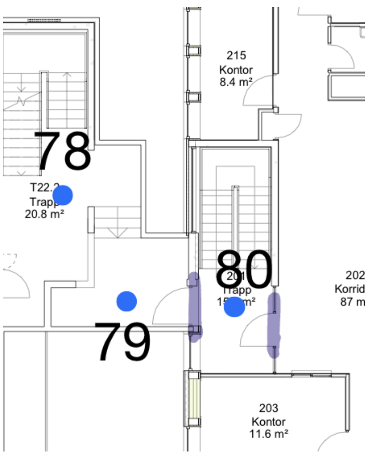

Figure 7.25: Identification map with markings of the doors for the location of the directional sign at node 80.

Figure 7.26: The directional signs for the doors of node 80.

7.2.3 Evacuation signage

Compared to wayfinding signage in a day-to-day situation, a well-functioning evacuation signage system are critical to ensure safe evacuation, reducing injuries and fatalities. As presented in the comparison of the optimal simplest path and the optimal paths using the shortest distance method, the daily wayfinding is not understood to negatively impact the emergency evacuation, as long as the emergency signage is appropriate and reliable.

In contrast to wayfinding signage, evacuation signage is subject to more regulations. Although these regulations do not explicitly dictate the design of the signs, they require that the signs are easily understood and readable under all conditions, as outlined in §11-11 from TEK17. Different colors can be used to represent different situations, with green typically indicating emergency routes. Therefore, using green for emergency evacuation signs is highly practical. At Solli DPS, the design of the emergency evacuation signs aligns with recommendations from relevant literature and regulations. They are green signs that are well-lit, featuring both arrows and a running man symbol.

Upon comparison, it became evident that the simplest path often coincides with or passes by the designated emergency exit. However, in everyday situations, when individuals only pass by an emergency exit without awareness of its existence, there is a risk that they may not recognize it as a viable option during an emergency. Hence, the presence of a clear and distinct emergency exit sign becomes crucial in these cases, both in terms of its design and placement. For instance, the shortest distance method indicates that exit point 133, shown in Figure 7.15, is the optimal path for multiple starting points in the corridor of Building D. Nevertheless, this exit is not commonly utilized in daily wayfinding. Consequently, it might be challenging to notice this exit, particularly as it is accessed through a closed door along the corridor wall. To address this issue, the evacuation signage system should consider implementing an emergency sign not only on the door itself but also hanging from the ceiling, with an arrow indicating the direction towards the door. Adopting such an approach to evacuation signage enhances visibility and ensures a safe evacuation process.

As mentioned earlier, the emergency evacuation strategy at Solli DPS is based on a multiple path approach, ensuring that occupants, regardless of their location within the building, always have visibility of signage indicating at least two possible evacuation routes.

The fact that this is a static evacuation guidance system emphasizes the importance of having signage for multiple paths simultaneously to facilitate safe evacuations. By having multiple options available, occupants can choose an alternative route if one path becomes inaccessible due to a hazard or obstruction. This approach aligns with the regulations concerning fire cells stated in TEK17 §11-8, which emphasizes the importance of having multiple evacuation paths available when a room is of a certain size or contains equipment that increases the risk of emergencies, i.e., fires.

However, a multi-signage strategy can potentially introduce some confusion among occupants when determining which evacuation path to choose if all paths are unobstructed. In such cases, occupants may not necessarily be aware of the shortest path and could end up taking longer routes, which is undesirable when aiming to minimize evacuation time. Solli DPS has implemented drawings of possible evacuation paths on certain walls. However, these evacuation plans are sporadically placed and may not be the most intuitive source of information within a guidance system. The readability and effectiveness of escape route plans as a primary information source during evacuation have been questioned in the literature (Helbing et al., 2005). Furthermore, the research also highlights that when unsure, individuals are more likely to choose familiar paths. It is important to consider these factors when designing an effective evacuation signage system, as it should strike a balance between providing clear and easily understood guidance while considering the potential drawbacks of information overload or confusion among occupants.

Overall, the need for multiple path signage for emergency evacuation is important in a statical guidance system and aligns with the regulations. However, a focus on signage for the unfamiliar emergency exits when this is the optimal path for evacuation may reduce the evacuation time. As the findings in this thesis recommend for signage for the way out in daily wayfinding, an evacuation signage system that takes this into account in its signage may overall create a more comprehensive guidance system, increasing user experience in day-to-day activities and ensuring safe evacuation.

8 Limitations and further research

The limitations of the approach taken in this thesis mainly stem from the assumptions made in the optimization model in reference to the psychological features. The familiarity parameter is based only on reflections from Solli DPS and logical thinking based on these conversations. The assumptions are, therefore, greatly simplified. Additionally, the exclusion of nervousness is done due to previous research's emphasis on nervousness solely in reference to hazards. Nonetheless, given that the treatment center houses individuals who have the potential to comparatively be more vulnerable, nervousness and other similar psychological features may also influence human behavior in ways that have not been considered, which could affect path selection.

Additionally, the occupant scenarios also have limitations. Only multiple-time visitors as a collective designation are included, whereas there, in fact, will be differences within the group of multiple-time visitors, e.g., the second-time visitors versus the eight-time visitors. Also, individual differences between the visitors will be influenced by where in the building the patients have their sessions. Lastly, it is worth noting that disability has not yet been taken into account in these scenarios. This is because there are currently only two elevators in the building, one in Building A and the other in the interception between Buildings C and D. There are not many patients with physical disabilities at the center, and those who are disabled will have familiarity with the elevators. Also, the elevators are implemented in the model to be prioritized for those that need them. However, there is still a need to address the signage for these paths, which must be evaluated thoroughly to avoid confusion or reduced readability of the guidance system for people without disabilities.

Furthermore, the drafts for the directional and reassurance signs are prepared in line with relevant theory, giving the basic ideas for placement and design. However, as we are not graphical designers, the specific design and size of the elements may require professional input to ensure optimal readability. With the help of experts in the field of graphic design, the overall design of the signs can enhance the visual presentation and aesthetics.

Finally, in the last section of the recommendations for the guidance system, we touch upon the topic of evacuation signage. While we provide a brief discussion on the advantages and disadvantages of implementing a multiple path signage strategy for emergency evacuation, we have not conducted a detailed evaluation of the specific placement of emergency signs. However, this will be relevant for creating a comprehensive guidance system that addresses both daily wayfinding and emergency evacuation. Further research and consideration of the placement of emergency signs would be relevant.

We see two main possibilities for further research on this topic. Firstly, virtual reality (VR) technology is widely used to simulate emergency evacuation problems. Implementing this technology with a digital twin of the building at Solli DPS can contribute to collecting data on which path choices the occupants make with consideration to individuality. It will give further insight into which paths are familiar to the occupants and help categorize occupants into more nuanced occupant scenario groups. Gaining a deeper understanding of the occupant's route choices, their familiarity with the building, and further nuances of the occupant's scenarios at Solli DPS could provide valuable insight into improving the weighted sum approach. By doing so, we can achieve a more specified and accurate result. The digital twin could also further contribute to testing the effect of implementing the recommendations from this thesis, both in regard to the success of daily wayfinding and the efficiency of emergency evacuation.

Secondly, another essential point to consider is exploring the most effective wayfinding signs from a psychological standpoint using a more qualitative method. Studying how patients' mental state impacts their ability to read and make decisions based on wayfinding signs could improve the development of a guidance system that is tailored to the needs of facilities like Solli DPS. This type of research could be applied to similar health institutions and provide valuable information for their guidance systems as well.

Our trade-off between the optimal paths and methods highly focuses on the paths not contradicting human instincts. Additional research on the psychological features and the impact of the patient's mental state may influence what should be understood as the basis for conducting this trade-off evaluation. This could again influence what is understood to be the most applicable optimization method.

9 Conclusion

This thesis aims to develop a method for establishing a well-functioning guidance system within a complex building, with application to daily navigation and the process of finding the way out of the building. The research was motivated by observations made at Solli DPS, where patients encountered difficulties in navigating and exiting the building after their treatment sessions. The thesis utilizes optimization modeling, which is commonly used in the setting of emergency evacuation, to define the simplest path in a day-to-day situation. This will serve as the foundation for establishing a well-function guidance system. The goal is to enhance user experience, minimize frustration, and reduce wasted time.

The main factors identified as having the most impact on path choices in a day-to-day situation are architectural features, familiarity, and human instincts. By considering these factors through four different multi-objective optimization approaches, we seek to establish a definition of the simplest path. Comparing the optimization methods, the weighted sum approach with equal weights is returned as the most applicable for defining simplicity in a complex building such as Solli DPS. Building on this, the thesis proposes implementing the optimal paths found by the weighted sum approach with equal weights as the basis for establishing the guidance system.

Furthermore, it is crucial to incorporate the optimization findings into the guidance system, considering the targeted audience of the signage. Priority should be given to designing signage that aids those who are least familiar with the building, specifically the scheduled patients who make up the majority of occupants at Solli DPS. Additionally, a well-functioning guidance system should be preserved as reliable and intelligible among the patients. Therefore, it is recommended to provide signage for both the optimal exit route (using the simplest paths) and the route to the reception (using the most familiar path), whenever applicable. This reinforcement instills trust in the accuracy and reliability of the guidance system, ultimately improving the overall experience and ensuring that patients are directed to the appropriate exit.

Consistency in placement and design is of utmost importance in the process of designing the physical signs of the guidance system. The signs should provide relevant and precise information to the users. It is recommended to incorporate reassurance signs in the stairways on every building floor, using bold fonts to emphasize the most relevant details. Additionally, directional signs should be introduced at other crucial decision points. Symbols can enhance readability, and arrows should be utilized when they can indicate a specific direction without the possibility of being misinterpreted. When arrows are not applicable, words can be used to provide directions.

Finally, it is crucial to ensure that daily wayfinding does not critically negatively impact the emergency evacuation flow of the building. The signage for both daily wayfinding and emergency evacuation should be perceived and developed as a comprehensive guidance system. A comprehensive guidance system should aim to strike a balance between offering clear and easily understood directions, while also taking into account the potential drawbacks of information overload and confusion among occupants.

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Appendix

A1 Building Layout Drawings

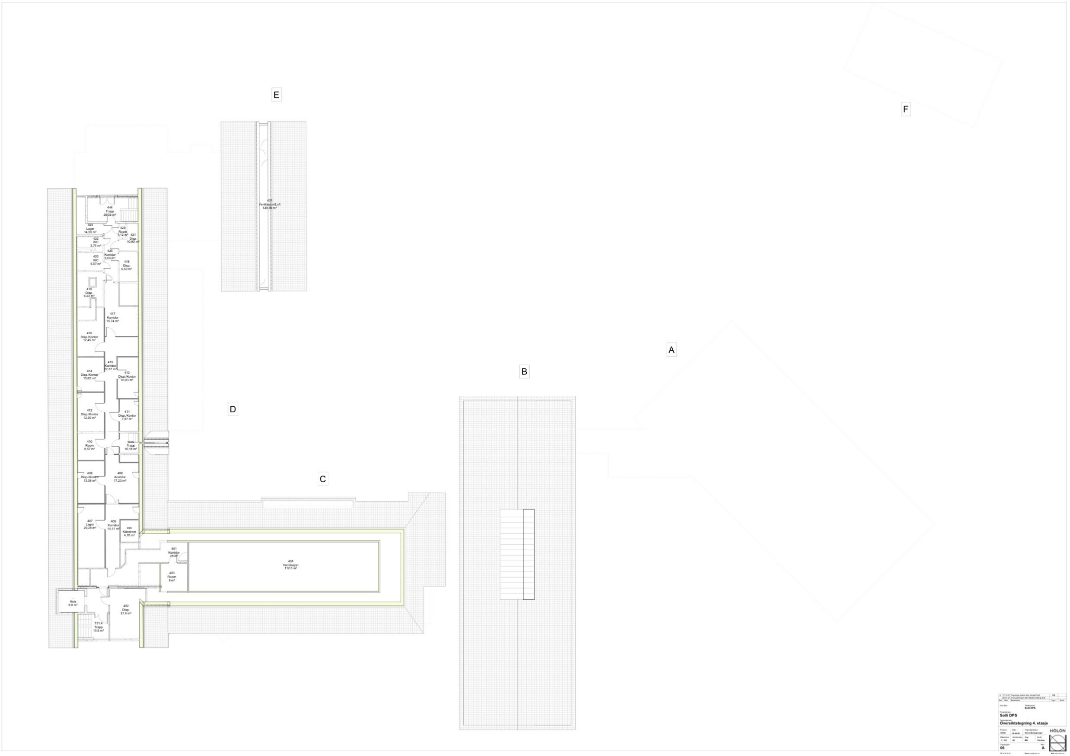

Figure A1.1: Building layout floor 4.

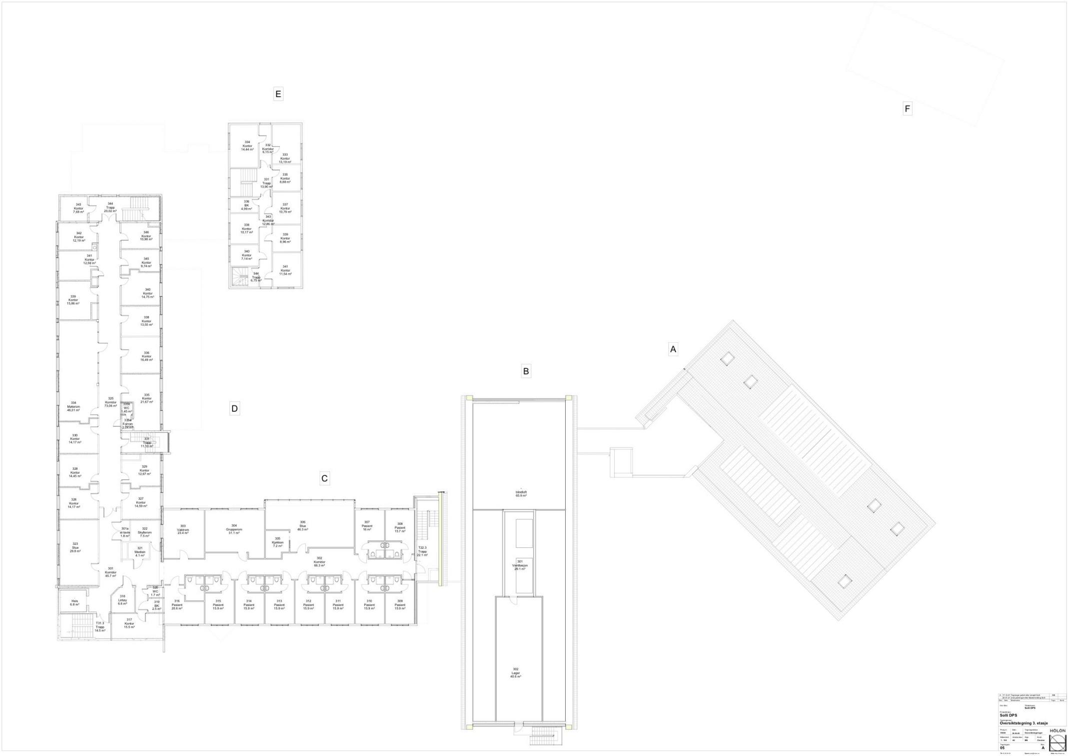

Figure A1.2: Building layout floor 3.

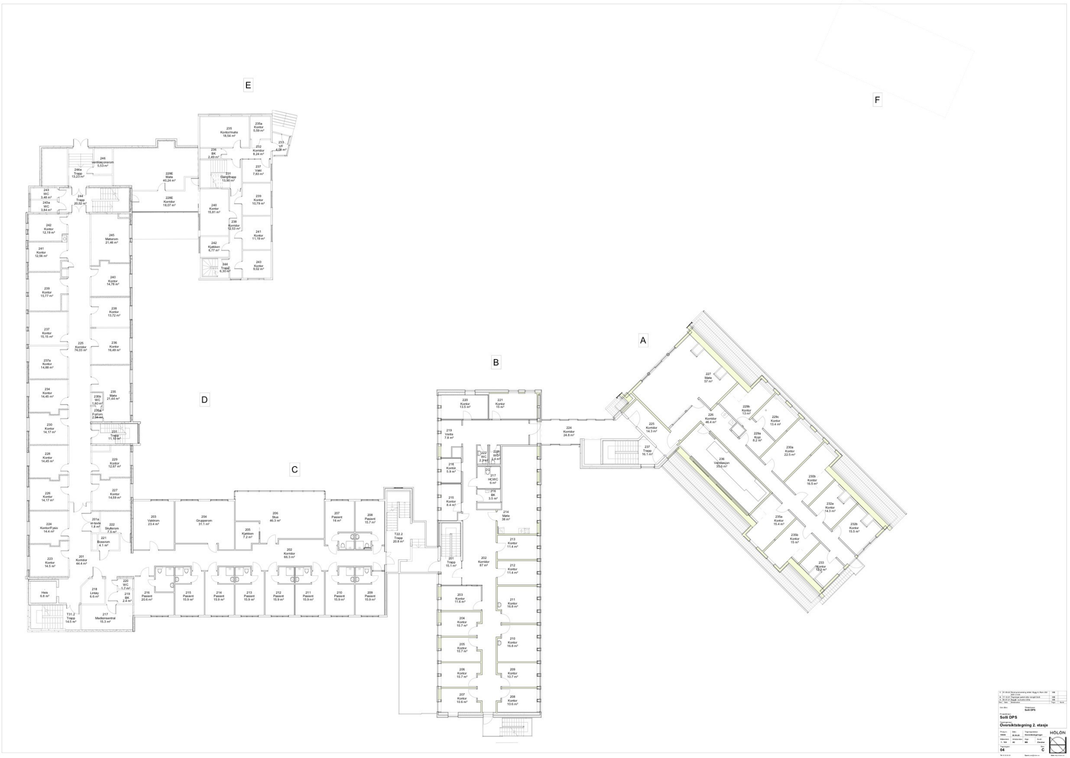

Figure A1.3: Building layout floor 2.

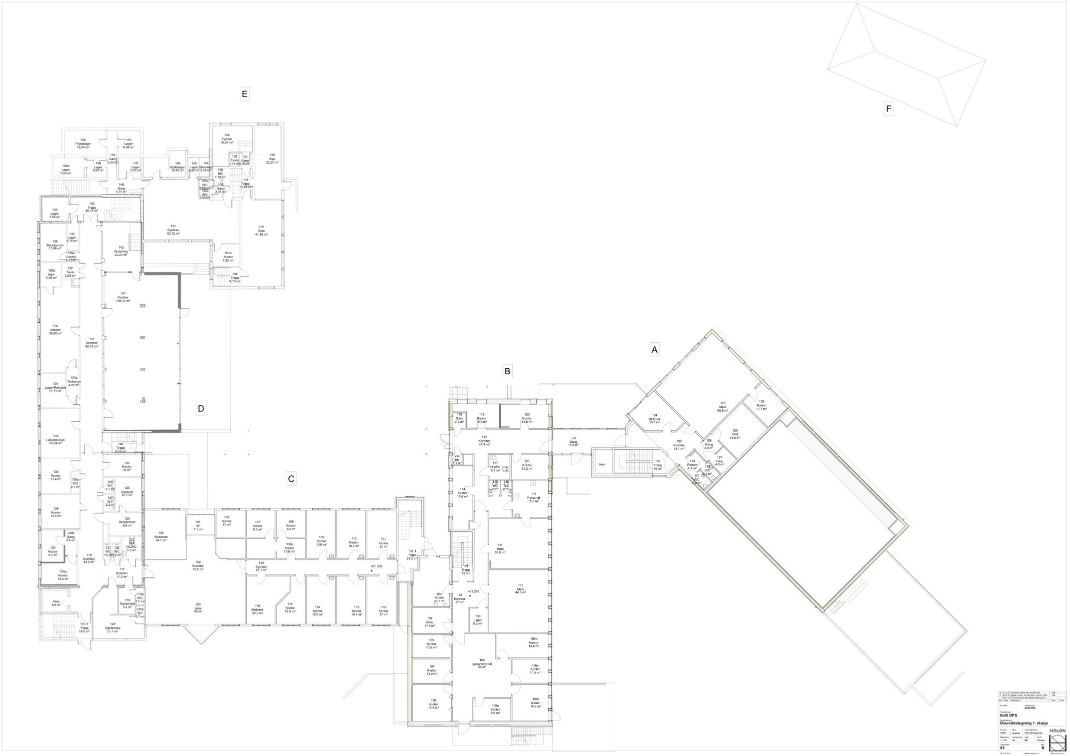

Figure A1.4: Building layout floor 1.

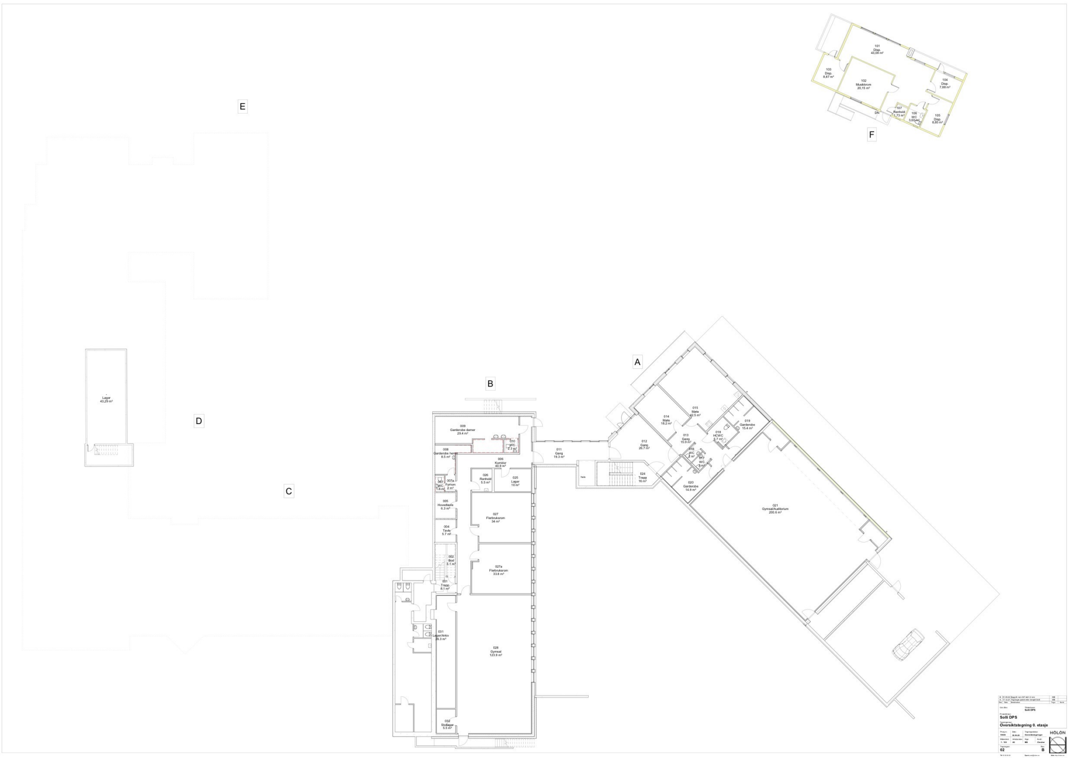

Figure A1.5: Building layout floor 0.

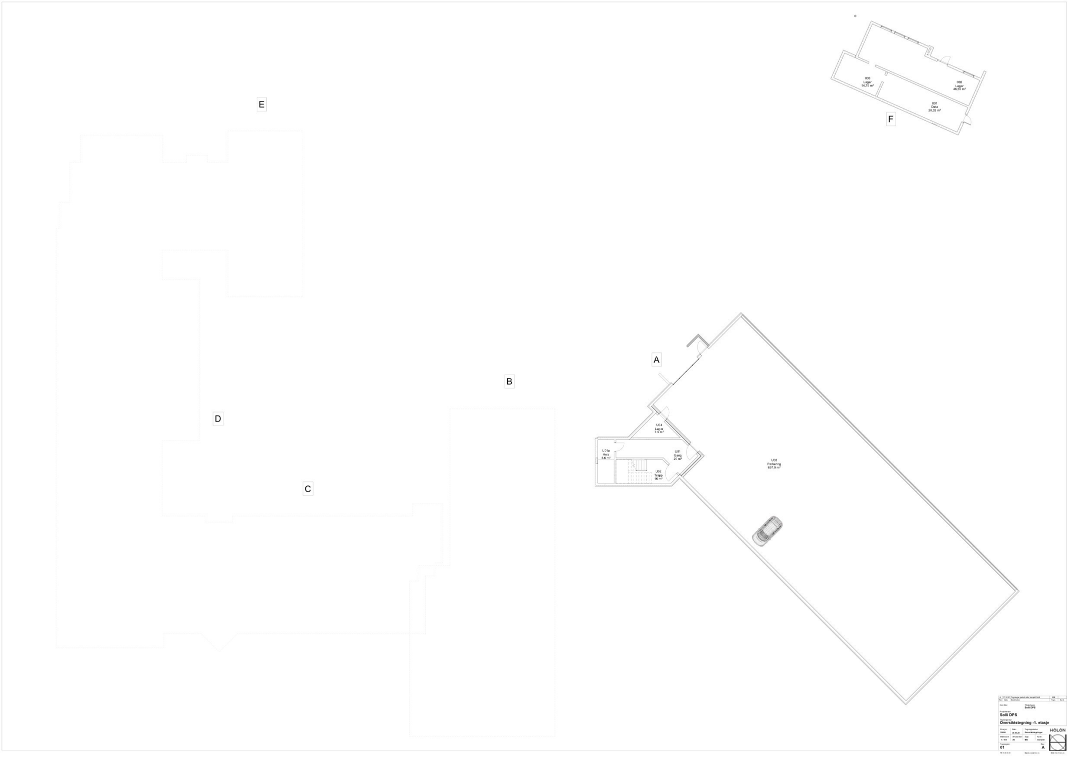

Figure A1.6: Building layout floor -1.

A2 Network Layout Drawings

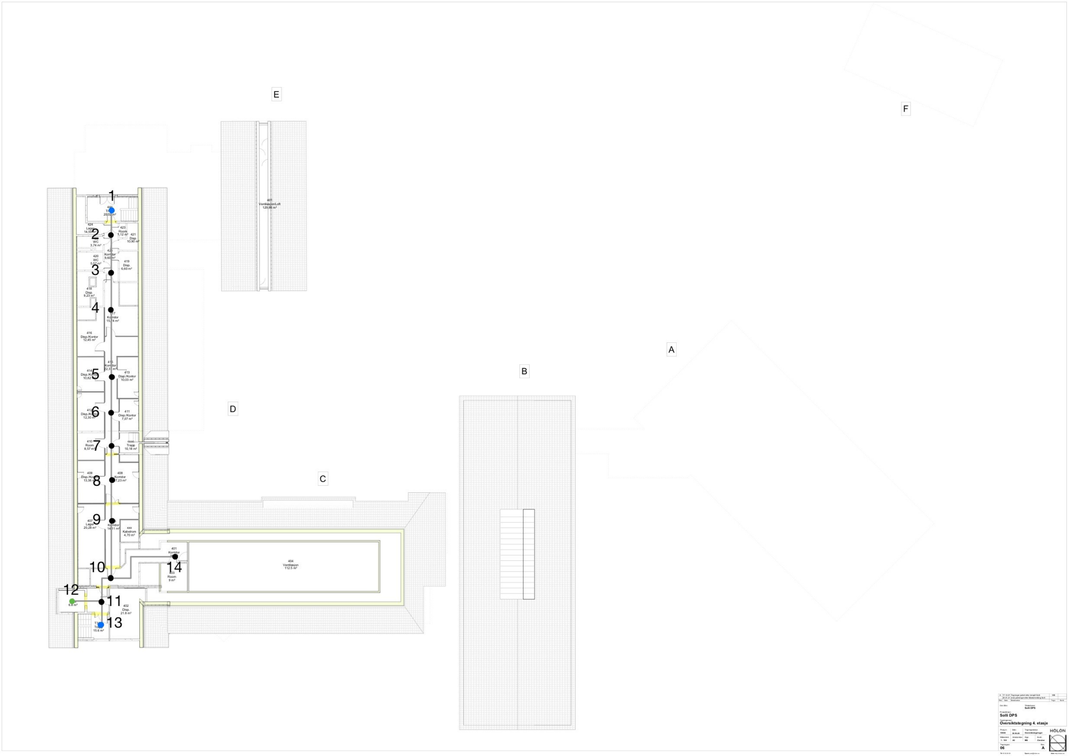

Figure A2.1: Network layout floor 4

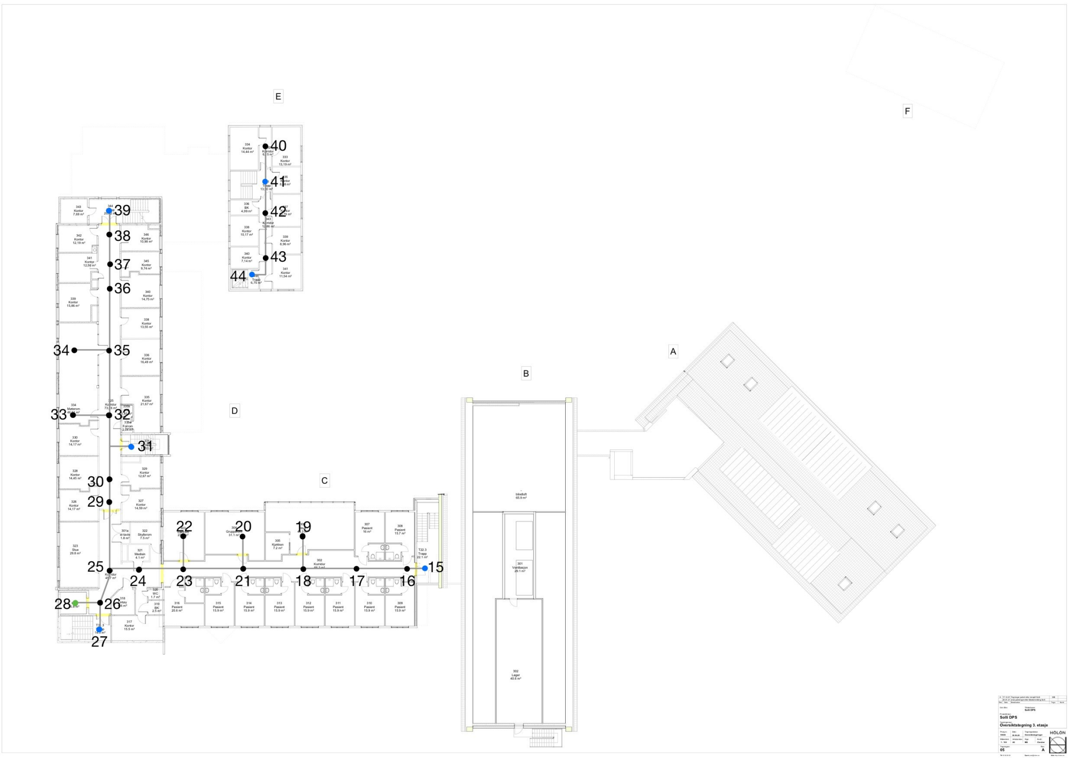

Figure A2.2: Network layout floor 3

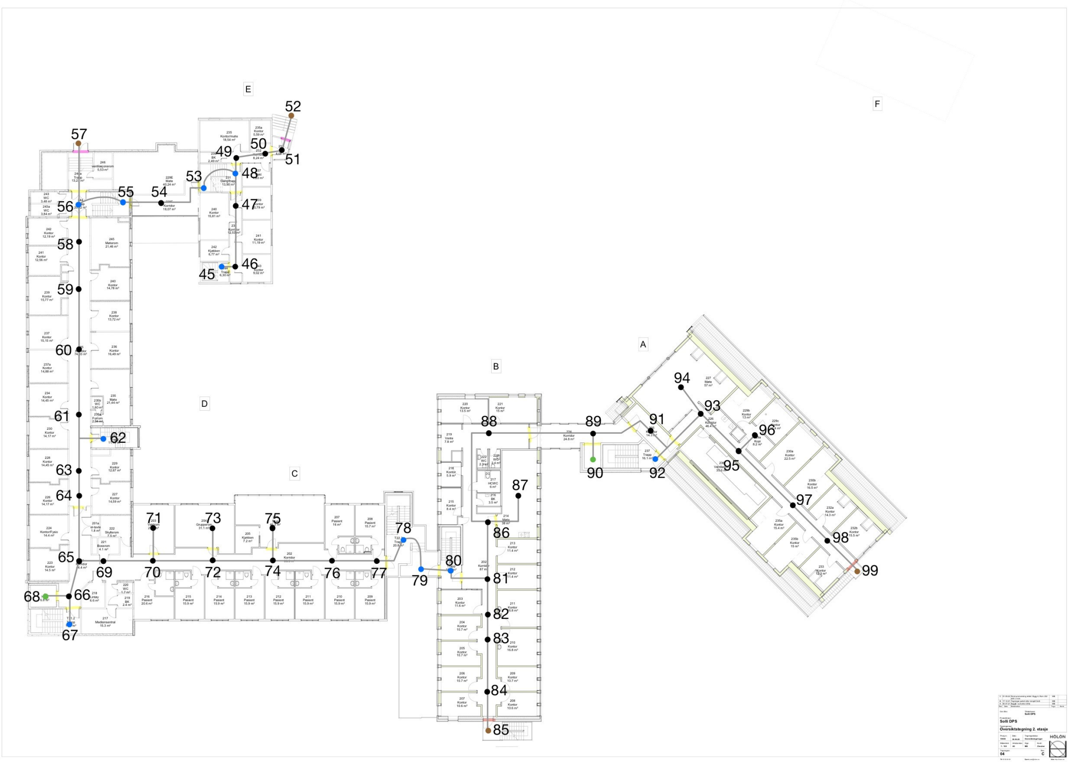

Figure A2.3: Network layout floor 2

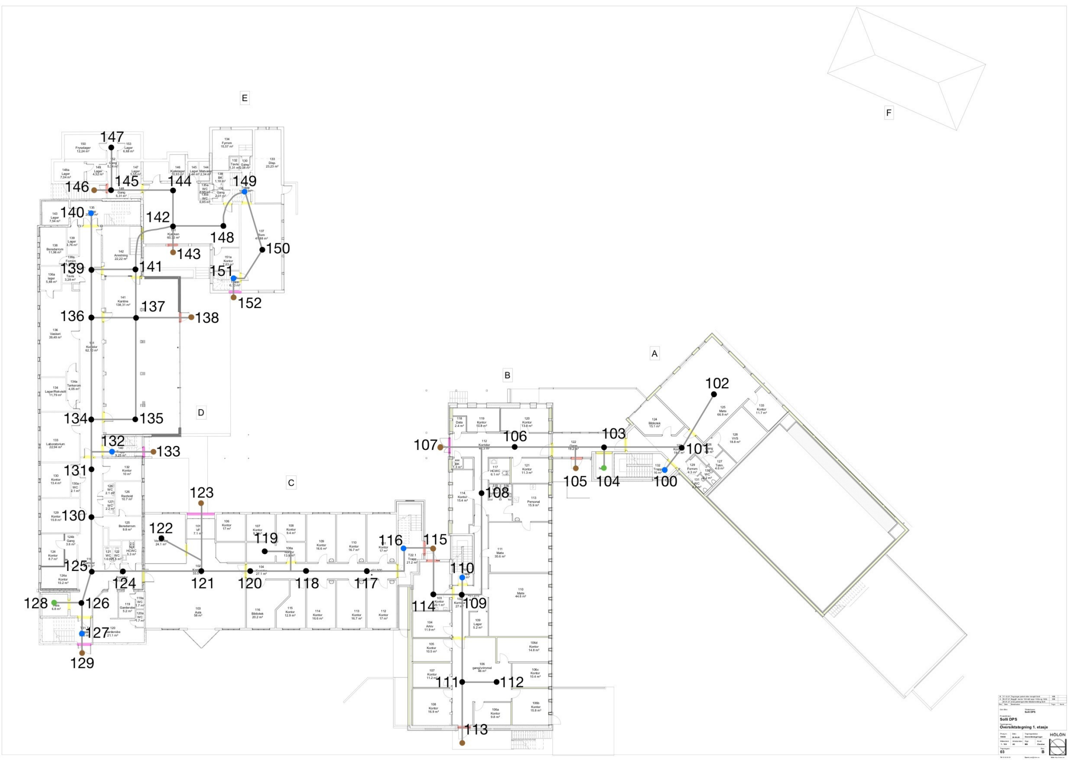

Figure A2.4: Network layout floor 1

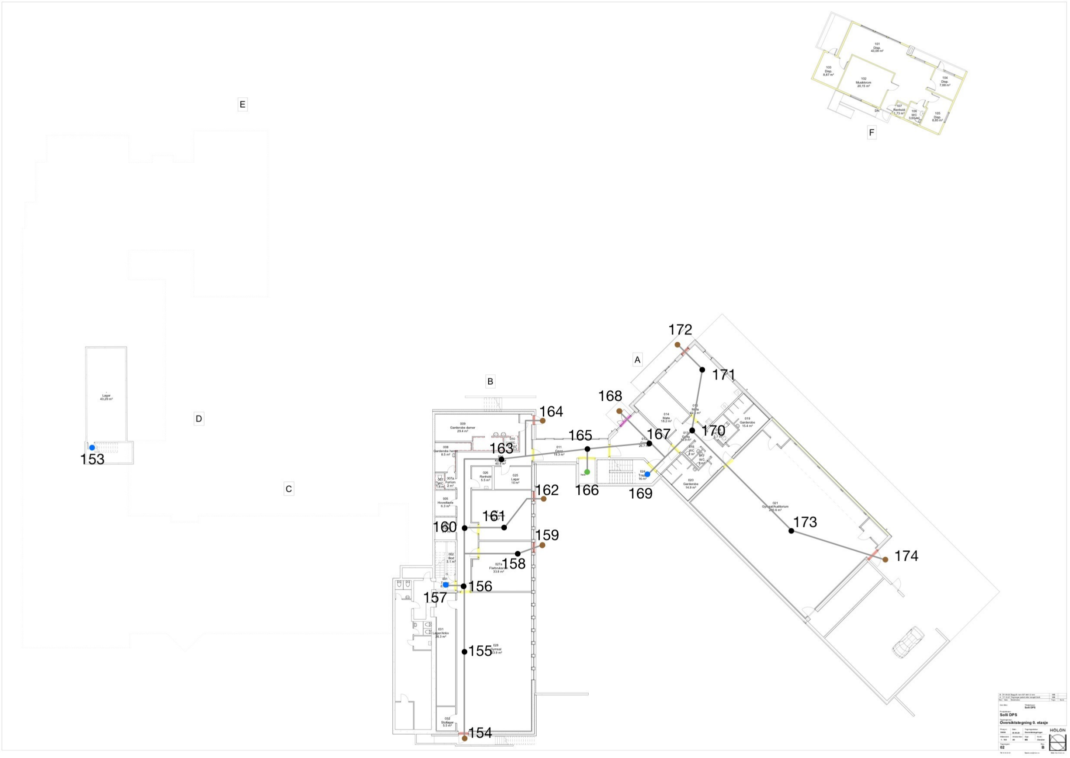

Figure A2.5: Network layout floor 0

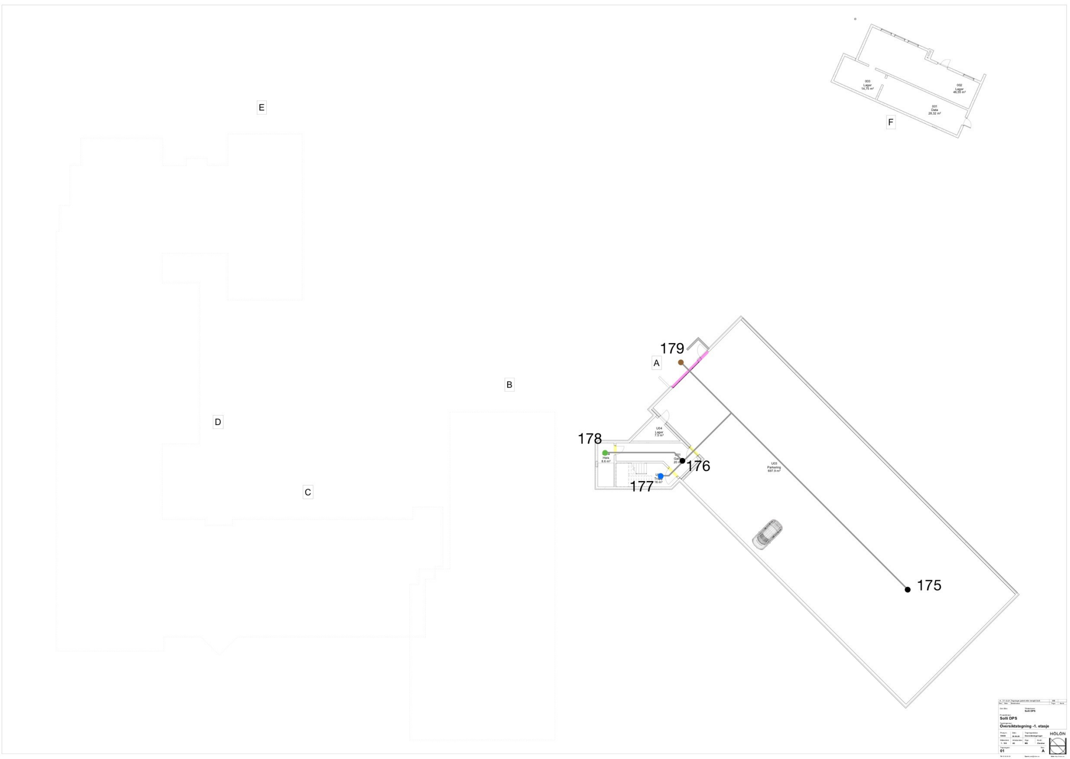

Figure A2.6: Network layout floor -1

A3 Specific Application to Solli DPS – The optimal paths

START NODE 3

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$3 \Rightarrow 4 \Rightarrow 5 \Rightarrow 6 \Rightarrow 7 \Rightarrow 8 \Rightarrow 9 \Rightarrow 10 \Rightarrow 11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 5

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$5 \Rightarrow 4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$5 \Rightarrow 6 \Rightarrow 7 \Rightarrow 8 \Rightarrow 9 \Rightarrow 10 \Rightarrow 11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 6

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$6 \Rightarrow 5 \Rightarrow 4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$6 \Rightarrow 7 \Rightarrow 8 \Rightarrow 9 \Rightarrow 10 \Rightarrow 11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 7

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$7 \Rightarrow 6 \Rightarrow 5 \Rightarrow 4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$7 \Rightarrow 8 \Rightarrow 9 \Rightarrow 10 \Rightarrow 11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 8

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$8 \Rightarrow 7 \Rightarrow 6 \Rightarrow 5 \Rightarrow 4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$8 \Rightarrow 9 \Rightarrow 10 \Rightarrow 11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 11

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 128$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$11 \Rightarrow 13 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 16

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 17

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$17 \Rightarrow 16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$17 \Rightarrow 16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 18

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$18 \Rightarrow 17 \Rightarrow 16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$18 \Rightarrow 17 \Rightarrow 16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 19

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$19 \Rightarrow 18 \Rightarrow 17 \Rightarrow 16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$19 \Rightarrow 18 \Rightarrow 17 \Rightarrow 16 \Rightarrow 15 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 20

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$20 \Rightarrow 21 \Rightarrow 23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$20 \Rightarrow 21 \Rightarrow 23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 21

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$21 \Rightarrow 23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$21 \Rightarrow 23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 22

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$22 \Rightarrow 23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$22 \Rightarrow 23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 23

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$23 \Rightarrow 24 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 24

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$24 \Rightarrow 25 \Rightarrow 29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$24 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 25

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$25 \Rightarrow 29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 29

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$29 \Rightarrow 30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 30

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$30 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 32

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 33

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$33 \Rightarrow 32 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$33 \Rightarrow 32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 34

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$34 \Rightarrow 35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$34 \Rightarrow 35 \Rightarrow 32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 35

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$35 \Rightarrow 36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$35 \Rightarrow 32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 36

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$36 \Rightarrow 37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$36 \Rightarrow 35 \Rightarrow 32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 37

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$37 \Rightarrow 38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$37 \Rightarrow 36 \Rightarrow 35 \Rightarrow 32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 38

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$38 \Rightarrow 39 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$38 \Rightarrow 37 \Rightarrow 36 \Rightarrow 35 \Rightarrow 32 \Rightarrow 30 \Rightarrow 29 \Rightarrow 25 \Rightarrow 26 \Rightarrow 27 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 40

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$40 \Rightarrow 41 \Rightarrow 48 \Rightarrow 49 \Rightarrow 50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 42

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$42 \Rightarrow 41 \Rightarrow 48 \Rightarrow 49 \Rightarrow 50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 43

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$43 \Rightarrow 42 \Rightarrow 41 \Rightarrow 48 \Rightarrow 49 \Rightarrow 50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 46

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$46 \Rightarrow 47 \Rightarrow 48 \Rightarrow 49 \Rightarrow 50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 47

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$47 \Rightarrow 48 \Rightarrow 49 \Rightarrow 50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 49

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$49 \Rightarrow 50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 50

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$50 \Rightarrow 51 \Rightarrow 52$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 58

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$58 \Rightarrow 59 \Rightarrow 60 \Rightarrow 61 \Rightarrow 63 \Rightarrow 64 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 59

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$59 \Rightarrow 60 \Rightarrow 61 \Rightarrow 63 \Rightarrow 64 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 60

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$60 \Rightarrow 61 \Rightarrow 63 \Rightarrow 64 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 61

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$61 \Rightarrow 63 \Rightarrow 64 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 63

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$63 \Rightarrow 64 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 64

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$64 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 65

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$65 \Rightarrow 64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 69

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$69 \Rightarrow 65 \Rightarrow 64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$69 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 70

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 56 \Rightarrow 57$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 71

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$71 \Rightarrow 70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 57 \Rightarrow 57 \Rightarrow$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$71 \Rightarrow 70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 72

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$72 \Rightarrow 70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 57 \Rightarrow 57 \Rightarrow$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$72 \Rightarrow 70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 73

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$73 \Rightarrow 72 \Rightarrow 70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 64 \Rightarrow 63 \Rightarrow 61 \Rightarrow 60 \Rightarrow 59 \Rightarrow 58 \Rightarrow 57 \Rightarrow 57 \Rightarrow$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$73 \Rightarrow 72 \Rightarrow 70 \Rightarrow 69 \Rightarrow 65 \Rightarrow 66 \Rightarrow 67 \Rightarrow 127 \Rightarrow 126 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 74

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$74 \Rightarrow 76 \Rightarrow 77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$74 \Rightarrow 76 \Rightarrow 77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 75

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$75 \Rightarrow 74 \Rightarrow 76 \Rightarrow 77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$75 \Rightarrow 74 \Rightarrow 76 \Rightarrow 77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 76

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$76 \Rightarrow 77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$76 \Rightarrow 77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 77

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$77 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 81

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 82

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$82 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$82 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 83

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$83 \Rightarrow 82 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$83 \Rightarrow 82 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 84

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$84 \Rightarrow 83 \Rightarrow 82 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$84 \Rightarrow 83 \Rightarrow 82 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 86

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$86 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$86 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 87

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$87 \Rightarrow 86 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$87 \Rightarrow 86 \Rightarrow 81 \Rightarrow 80 \Rightarrow 79 \Rightarrow 78 \Rightarrow 116 \Rightarrow 117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 88

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$88 \Rightarrow 89 \Rightarrow 91 \Rightarrow 92 \Rightarrow 100 \Rightarrow 169 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 94

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$94 \Rightarrow 93 \Rightarrow 92 \Rightarrow 100 \Rightarrow 169 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 95

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$95 \Rightarrow 93 \Rightarrow 92 \Rightarrow 100 \Rightarrow 169 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 96

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$96 \Rightarrow 95 \Rightarrow 93 \Rightarrow 92 \Rightarrow 100 \Rightarrow 169 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 97

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$97 \Rightarrow 95 \Rightarrow 93 \Rightarrow 92 \Rightarrow 100 \Rightarrow 169 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 98

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$98 \Rightarrow 97 \Rightarrow 95 \Rightarrow 93 \Rightarrow 92 \Rightarrow 100 \Rightarrow 169 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 101

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$101 \Rightarrow 103 \Rightarrow 106 \Rightarrow 107$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 102

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$102 \Rightarrow 101 \Rightarrow 103 \Rightarrow 106 \Rightarrow 107$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 106

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$106 \Rightarrow 107$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 108

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$108 \Rightarrow 107$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 109

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$109 \Rightarrow 108 \Rightarrow 107$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 117

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$117 \Rightarrow 118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 118

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$118 \Rightarrow 120 \Rightarrow 121 \Rightarrow 123$$

START NODE 120

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$120 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$120 \Rightarrow 121 \Rightarrow 123$$

START NODE 121

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$121 \Rightarrow 123$$

START NODE 122

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$122 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$122 \Rightarrow 123$$

START NODE 130

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 131

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 134

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 135

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$135 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$135 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 136

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$136 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$136 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 137

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$137 \Rightarrow 136 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$137 \Rightarrow 136 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 139

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage the reception, as this is the optimal exit)

$$139 \Rightarrow 136 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

Lexicographic ordering with familiarity ranked highest: (Familiar path for exiting the building, i.e., signage for the reception)

$$139 \Rightarrow 136 \Rightarrow 134 \Rightarrow 131 \Rightarrow 130 \Rightarrow 125 \Rightarrow 124 \Rightarrow 121 \Rightarrow 123$$

START NODE 150

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$150 \Rightarrow 151 \Rightarrow 152$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 155

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$155 \Rightarrow 156 \Rightarrow 160 \Rightarrow 163 \Rightarrow 165 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 158

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$158 \Rightarrow 160 \Rightarrow 163 \Rightarrow 165 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 161

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$161 \Rightarrow 160 \Rightarrow 163 \Rightarrow 165 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 163

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$163 \Rightarrow 165 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 171

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$171 \Rightarrow 170 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 173

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$173 \Rightarrow 170 \Rightarrow 167 \Rightarrow 168$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

START NODE 175

Weighted sum approach with equal weights: (Simplest path for exiting the building, i.e., signage for exit)

$$175 \Rightarrow 179$$

Lexicographic ordering with familiarity ranked highest:

Not Applicable in line with recommendations for the guidance system

A4 Specific Application to Solli DPS – The guidance system

In general, the recommendations presented in the thesis are applicable to Solli DPS since it serves as the case objective. The main recommendations include using reassurance signs in the stairways and directional signs at critical decision points. This appendix provides a detailed explanation of how the optimization findings will impact the guidance system at Solli DPS, such as where the signs should be placed and what information they should contain. It's important to note that the thesis findings specifically focus on finding the way out of the building and do not provide detailed recommendations for navigating within the building. Therefore, the following sections will offer specific recommendations for designing signs related to exiting the building based on the optimal paths outlined in Appendix A3.

As mentioned, all stairways should have reassurance signs. The respective floor should be highlighted with bold letters, and give intel to which floor the nearest exit is and at what floor the reception is. If the reception is the nearest exit, then only sign for the reception. All signs must be adjusted to the number of floors the given stairway reaches. None of the stairways in Buildings A and B should include the reception, as there is no natural path that will provide a reasonable route to the reception. An example reassurance sign is given in Figure A4.1. Additional spacing in the sign, represented by ..., has been included for Solli DPS to accommodate their specific navigation needs within the building.

Figure A4.1: An example of a reassurance sign that is applicable for the stairway at node 1.

Furthermore, the implementation of directional signs at critical decision points at Solli DPS will be important to secure trust in the guidance system and enhance successful wayfinding. The following section will present the critical decision point identified in the building.

First, there should be one directional sign at the wall by node 25 on the 3rd floor. This sign should sign for “Resepsjonen” in the left direction and “Utgang” in the right direction.

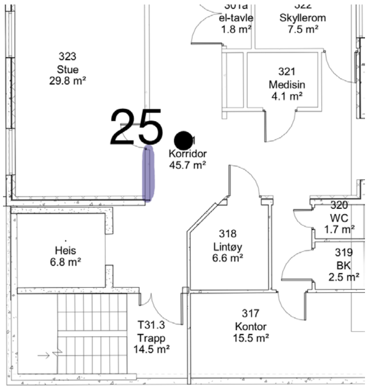

Figure A4.2: Identification map with markings of the wall for the location of the directional sign at node 25.

Figure A4.3: The directional sign at the wall of node 25.

Second, there should be a directional sign located at the mid-corridor wall of node 48 on the 2nd floor with a sign indicating "Utgang" to the left. This sign is followed by another directional sign at the wall of node 49 saying "Utgang" to the right.

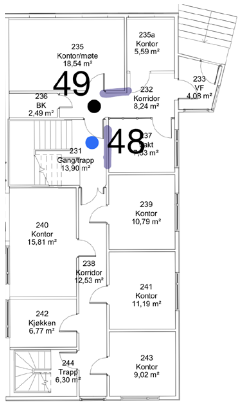

Figure A4.4: Identification map with markings of the wall for the location of the directional sign at nodes 48 and 49

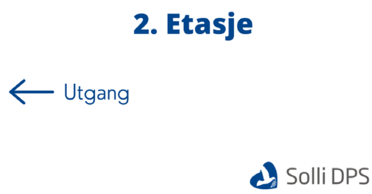

Figure A4.5: The directional sign at the wall of node 48.

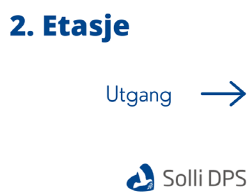

Figure A4.6: The directional sign at the wall of node 49.

Third, there should be a directional sign on the wall by node 65 on the 2^{nd} floor indicating "Utgang" to the right and "Resepsjonen" to the left.

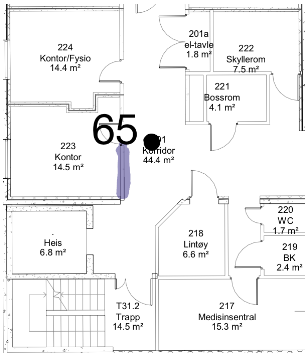

Figure A4.7: Identification map with markings of the wall for the location of the directional sign at node 65.

Figure A4.8: The directional sign at the wall of node 65.

Furthermore, there should be a few directional signs located in the section of the building connecting Building B and Building C on the 2^{nd} floor. There shall be one directional sign on the wall between nodes 81 and 86 indicating "Resepsjonen" to the left, followed by a sign on the door into stairway 80 saying "Til Resepsjonen". The "Til Resepsjonen" sign should also be on the door out of stairway 80 into stairway 79. Lastly, there shall be a directional sign on the wall by node 88 indicating "Utgang" to the right.

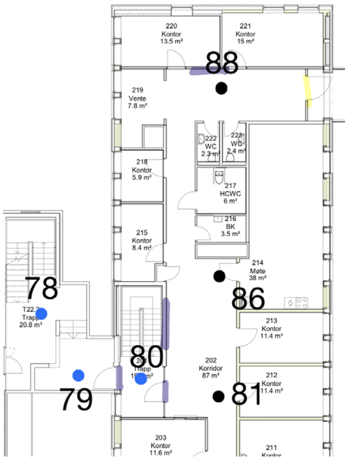

Figure A4.9: Identification map with markings of the walls and doors for the location of the directional signs at node 78:81, 86 and 88.

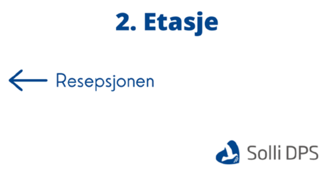

Figure A4.10: The directional sign at the wall between node 81 and 86.

Figure A4.11: The directional sign on the door to and from stairway 80, moving from node 81 to node 79.

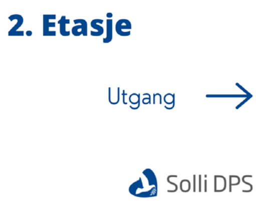

Figure A4.12: The directional sign at the wall of node 88.

The next directional sign is located at the wall of node 126 on the 1st floor indicating "Resepsjonen" to the left.

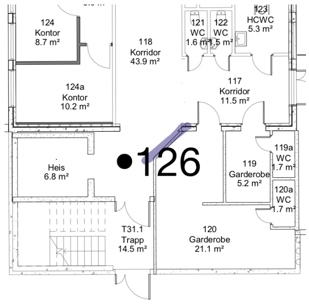

Figure A4.13: Identification map with markings of the wall for the location of the directional sign at node 126.

Figure A4.14: The directional sign at the wall of node 126.

Fruther, there should be a directional sign located at the door leading to stairway 151 at the 1st floor saying "Utgang".

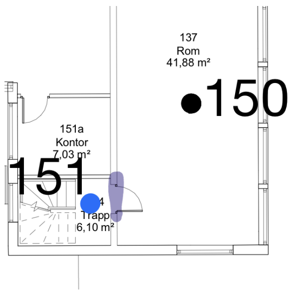

Figure A4.15: Identification map with markings of the door for the location of the directional sign at node 151.

Figure A4.16: The directional sign on the door to stairway 151.

Lastly, there should be one directional sign on the wall by node 163 on the 0^{th} floor indicating "Utgang" to the right.

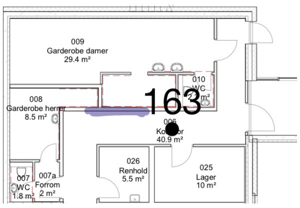

Figure A4.17: Identification map with markings of the wall for the location of the directional sign at node 163.

Figure A4.18: The directional sign at the wall of node 163.