EMERGING TRENDS AND TECHNOLOGIES IN THE BUILT ENVIRONMENT – HOSPITAL AND HOTEL BUILDINGS

Lappeenranta–Lahti University of Technology LUT

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ABSTRACT

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For companies it is crucial to comprehend what trends and technologies are emerging to meet customer demands and gain a competitive advantage. This study aims to identify emerging trends and technologies in the built environment of hospitals and hotels, recognize industry challenges and pain points, and grasp the future state of the hospital- and hotel-built environments. This thesis was conducted using qualitative research methods consisting of interviews with experts from a variety of industry-leading service and technology companies and a literature review that aims to complement and validate the interview findings.

The outcome of this study is a set of trends and technologies relating to the hospital and hotel environment today, including their respective driving forces. Additionally, the analysis presents a hypothetical user journey in the most technologically advanced hospital and hotel of the future. As an example, the study findings indicate that staffing shortages are a global challenge in both industries. To address this hospital- and hotel-built environments are increasingly adopting specific types of technologies to enable automation. The findings raise opportunity areas for the case company and other companies alike, which are also presented in the analysis.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
Teknis-luonnontieteellinen
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Dana Koniel

Nousevat trendit ja teknologiat rakennetussa ympäristössä
Sairaala ja hotelli rakennukset

Diplomityö
2023
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Yrityksille on olennaista ymmärtää, mitkä asiat ohjaavat toimialojen muutosta ja mitkä trendit ja teknologiat ovat nousemassa esiin, jotta asiakkaiden tarpeisiin osattaisiin vastata ja yrityksen kilpailukykyä edistää. Tämän tutkimuksen tavoitteena on tunnistaa sairaaloiden ja hotellien rakennettun ympäristön nousevia trendejä ja teknologioita, selvittää toimialakohtaisia haasteita, sekä hahmottaa rakennetun ympäristön tulevaisuuden tilaa kyseisissä rakennustyypeissä. Tutkimus toteutettiin kvalitatiivisilla menetelmillä, jotka koostuivat alan johtavien palvelu- ja teknologiayritysten asiantuntijoiden haastatteluista sekä kirjallisuuskatsauksesta, jonka tarkoituksena oli täydentää ja validoida haastattelutuloksia.

Lopputuloksessa on listattu sairaala- ja hotellirakennuskohtaiset trendit ja teknologiat, sekä haasteet ja kipupisteet. Analyysissa esitetään myös näkemys tulevaisuuden teknologisesti edistyneimmästä sairaalasta ja hotellista. Tuloksissa nousee esiin esimerkiksi globaali henkilöstöpula molemmilla toimialoilla. Tämän ratkaisemiseksi yhä useammat sairaalat ja hotellit ovat ottaneet käyttöön tietyntyyppisiä automaatioratkaisuja. Löydökset nostavat esiin liiketoimintamahdollisuuksia työn toimeksiantajalle, sekä muille vastaavanlaisille toimijoille. Näkemykset liiketoimintamahdollisuuksista esitellään työn loppuvaiheessa.

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ABBREVIATIONS

ROI	Return of Investment
IoT	Internet-of-Things
IoMT	Internet-of-Medical-Things
HVAC	Heating, Ventilation and Air Conditioning
VR	Virtual Reality
RFID	Radio-Frequency Identification
AC	Air Conditioning
AI	Artificial Intelligence
DT	Digital Twin
ML	Machine Learning
OR	Occupancy Rate
ESG	Environmental, Societal, Governance
PMS	Property Management System
API	Application Programming Interface
PoC	Proof of Concept
EHR	Electronic Health Record
RevPar	Revenue Per Available Room
TRevPar	Total Revenue Per Available Room
RTLS	Real-Time Locating System
BMS	Building Management System
EMR	Electronic Medical Record
AGV	Automated Guided Vehicle

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1 Introduction

Trends and the development of technology have greatly impacted how buildings have evolved and how they will continue to evolve in the future (Indesignlive.sg, 2018). For instance, global megatrends such as sustainability and urbanization have largely affected the way most buildings today are designed, built and how they operate. The development of technology has widely contributed to the way these trend driven needs and requirements are addressed. (Stepanek, 2022) (Infineon, 2019)

Government-led sustainability initiatives have created new requirements and put pressure on building developers and owners to become more sustainable (Bradford & Parry, 2022). Urbanization means that existing buildings will need to find ways to maximize the potential of built spaces and accommodate the growing population in cities. Technology is being actively used to tackle these challenges (Infineon, 2019). Solutions that optimize energy use in buildings, as well as technologies that optimize space usage have become more popular in the built environment (Swedberg, 2019).

While these above-mentioned exemplary megatrends have impacted the building sector in many ways, more often their practical implications and the way technology is used to tackle these new emerging trends differs based on the building type itself. For instance, the Covid-19 pandemic has created new hygiene standards and demands for the built space that have been addressed, for instance, with the use of different types of contactless technologies. (Nuutinen, et al., 2021) (Giacobbe, 2020) Hospital buildings have relied on extensive adoption of contactless patient monitoring systems that utilize Artificial Intelligence (AI) and Internet-of-Things (IoT) technologies and in hotel buildings physical touchpoints were limited with the adoption of contactless check-in, check-out and guest requests with the use of online registration systems, robot concierges and digital room keys (Sarma, 2020) (Sorrells, 2020) This demonstrates that while the Covid-19 driven trend has been to create contactless operations, the technologies associated, and the use cases catered to, are different based on the building type. (Von Groddeck & Schwarz, 2013)

Thus, from a service providers perspective it becomes crucial to understand what and why trends are emerging, what and how technology is used or could be used, and how are the practical implications of these trends and technologies unique to each building segment. This

type of information in turn can help companies match their offering to meet market demands and provide real customer value. (Von Groddeck & Schwarz, 2013)

The next section 1.1 defines trend management. Section 1.2 explains the thesis context from the case company's perspective and the thesis scope. The objective, research questions and outcome are presented in section 1.3. Section 1.4 presents the methods of research. Section 1.5 presents the structure of the thesis. For additional context and background, appendix 2 defines the key concepts and terminology used in this study.

1.1 Trend management as thesis context

Nowadays, trends are understood to be critical for the development of foresight as well as a key starting point for strategy development. Dealing with trends is seen to be strategically important for the business model of a company. Thus, making trends crucial in the development of new business opportunities. (Von Groddeck & Schwarz, 2013) Trend management is a means of preparation for change and fluctuation. (Rubin, 2022) It has been argued that trends incorrectly interpreted or poorly understood can significantly impact the effectiveness of an implemented strategy. Thus, a key aspect of trend management in organizational practice is in what way or how a trend is perceived. (Von Groddeck & Schwarz, 2013)

There are several slightly contradicting definitions for the term trend. The traditional being that a trend is a fundamental, ongoing societal change that happens over a lengthy time. The modern definition, however, highlights how trends are short-term phenomena like music or fashion. A third definition perceives trends as being a complex phenomenon and that their lifespan is not accurately measurable. However, it can be concluded that a trend is defined as something new, a new phenomenon. While the objects related to a trend do not necessarily need to be new, they are usually somewhat altered. (Von Groddeck & Schwarz, 2013) A trend can also be part of a megatrend. A megatrend, on the other hand, refers to a single phenomenon or a group of phenomena or trends that dominantly determine the direction or overall quality of the future. Today's megatrends are, for instance, sustainability and digitalization. (Rubin, 2022)

There is a misconception that the course at which a trend will evolve can be predicted, which is not the case. The purpose of identifying trends should be to understand and diagnose them. From the organization's perspective, it might be more insightful to determine the origins of the trend rather than look for views on how a trend will evolve. (Von Groddeck & Schwarz, 2013)

Trends can be researched from external and internal sources. For instance, external source information can be gathered from customers, media (e.g., news), competition, industry reports, and publications whereas internal information sources can be employees, an internal network of experts, and internal documents. It is seen that external sources are more reliable and robust, as they are not limited to the company's internal (subjective) view. An external view could show companies trends and technologies that are not yet on their radar. To maintain a rational view on a company, a mix of both external and internal sources is crucial. (Durst & Durst, 2017)

1.2 Thesis context and scope

This thesis is carried out for a global manufacturing and service business company which employs over 60 000 people globally. The company has a lifecycle business model, and it provides value to its customers across the lifecycle of buildings (Company's website, 2022). This study is conducted for the Digital Services team which is part of the company's global Maintenance Business unit. The Digital Services team is responsible for the commercialization of the company's various digital services that serve its Maintenance Business unit's customers globally. One element in the company's latest strategy phase (2021) is creating new, sustainable solutions that deliver new sources of customer value (Company's website, 2022).

As the study is conducted for the company's global Maintenance Business unit, the focus of this study is to research trends and technologies that are emerging in the built environment, thus meaning buildings that are in their operational phase. Thus, aspects relating to the buildings' design, and construction phases are not within the scope of this study. Similarly, emerging technologies that are researched are related to the built environment. Furthermore, there is no geographical focus for this study rather the aim is to research trends and technologies that are not geographically limited to a specific area.

The two building types that this study focuses on are: hospitals and hotels. The case company has conducted previous research around the trend and technology landscape of buildings in general. These studies have covered either all building segments more broadly or specific building types or phases of the building's lifecycle. No studies have been conducted that focus specifically on hospitals and hotels, and their built environment. Thus, these building types have been chosen.

Based on initial research, there is available literature in which built environment trends and technologies have been investigated. Most of the research has explored industry-wide trends and technologies and there is less research that has examined the hospital and hotel building segments specifically. While there are numerous online articles and websites which have examined similar topics, there is no academic-level research available that has examined the topic with a similar research method or scope.

As the study is conducted for a case company, certain requirements have been made. For instance, the findings of this research will be used to derive opportunity areas and implications from the company's standpoint, making the study results especially useful for the case company and other companies alike. This is what also makes this study distinctive from those with a similar topic.

1.3 Thesis objectives, research questions and outcome

The objective of this thesis is to understand what trends and technologies are emerging in the built environment of hospitals and hotels. Four research questions have been formed to support with achieving the objective:

- **RQ1: What are the pain points and challenges faced by hospitals and hotels?**
- **RQ2: How are these pain points and challenges being addressed through emerging trends and technologies?**
- **RQ3: Which specific use cases are being catered to by these emerging trends and technologies?**
- **RQ4: What will be the key features and capabilities of a technologically advanced hospital and hotel of the future?**

This thesis aims to identify emerging trends and technologies in the hospital and hotel-built environments, which forms the main objective. The first research question (RQ1) aims to understand the potential origins of emerging trends and technologies, by identifying pain points and challenges. The second research question (RQ2) aims to find a correlation between the emerging trends and technologies and the identified pain points and challenges. The third research question (RQ3) aims to gain practical knowledge. The final research question (RQ4) aims to understand how hospitals and hotels will evolve considering the trends and technologies will gain more widespread adoption. Although this cannot be predicted, the findings can serve as signals for the future.

Based on the research findings the outcome of this study is a table consisting of trends and technologies which are emerging in the hospital and hotel-built environment, including an analysis of pain points and challenges correlating to the identified trends and technologies. Additionally, the outcome consists of a hypothetical illustration of the future's technologically advanced hospital and hotel and an analysis of opportunity areas for the case company and other service providers.

1.4 Research methods

The method of research for this study is qualitative, as data is gathered in the form of primary data (interviews) and secondary data (literature) (Streefkerk, 2019). The interviewees will represent companies that act as service providers for the respective building types. There will be both internal and external expert interviews. The interview questions will be defined before the interviews are held with a semi-structured frame. The questions will be open-ended to allow discussion and follow-up questions. Questions will be sent to the interviewees prior, to allow them to prepare. The interviews will be transcribed and analysed using thematic analysis to enable the identification of specific topics, patterns, and ideas (Caulfield, 2019). The input collected from literature will be utilized to situate the research in an existing body of work.

Thematic analysis was chosen as the analysis approach due to its applicability to the chosen data gathering methods. Additionally thematic analysis allows the researcher to discover people's knowledge, opinions, and views. The thematic analysis process follows a six-step

process which includes familiarization, coding, generating themes, reviewing themes, defining, and naming of themes, and writing up. (Caulfield, 2019)

The six-step analysis approach chosen for this study is the most common process for thematic analysis. It this context the first step is to *familiarize* the data, in a form of reading through the transcribed interviews. Second, the transcribed data is *coded* by highlighting the relevant sections, phrases or sentences and then accordingly labelling the codes. Next, the labels are used to *generate themes* and identify patterns. The generated themes are then be *reviewed* to validate that they accurately represent the data. The final list of themes is consequently *defined and named* for easier comprehension. Finally, the analysis is conducted by *writing up* the results. (Caulfield, 2019)

As part of the research, a theoretical framework will be constructed, which is the secondary data source of this study. The theoretical framework of this study will be introduced in a form of a literature review that introduces the concepts, definitions and theories related to the research topic. Its purpose is to act as a structure to support the research and its findings. The materials that will be used in the literature review will be from external, online sources. All sources for this study will be evaluated in terms of credibility, innovation, and relevancy during the literature research process. The literature will consist of sources such as governmental reports, academic publications, websites, and articles.

1.5 Thesis structure

This section presents the high-level thesis structure. The thesis consists of five main chapters: introduction, literature review, empirical findings, results, and conclusions. The thesis structure along with each chapter's inputs and outputs are depicted in Figure 1 below.

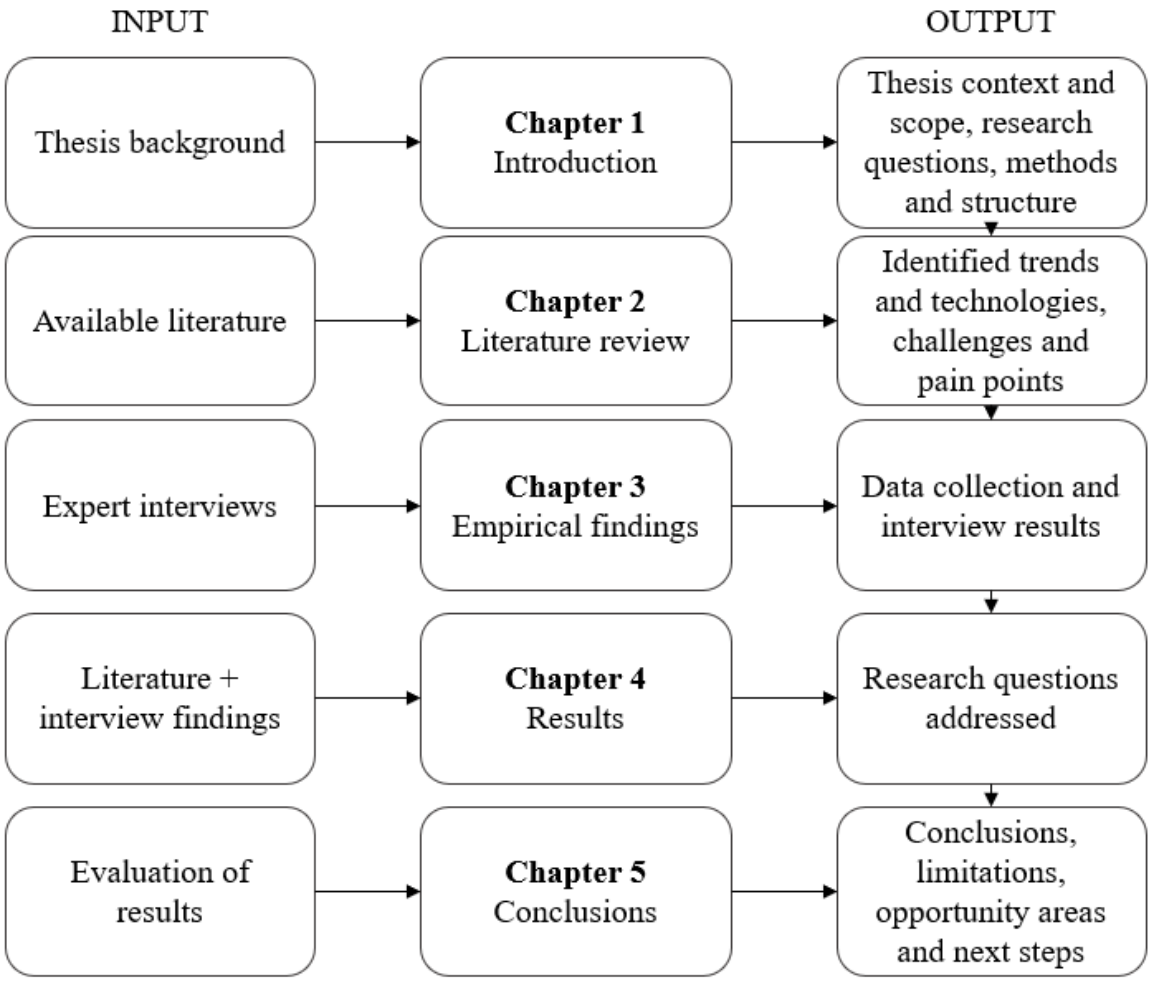

Figure 1 Research structure

The first chapter is the introduction, and its main contents are the thesis context, scope, research questions, research methods and the thesis structure. The second chapter is the literature review of the study, and it examines the themes and topics related to the study objectives with the aims of complementing the empirical findings of this study. The third chapter presents the analysis of the empirical findings based on the expert interviews. The fourth chapter is results. It examines the research findings as a whole consisting of both literature and empirical findings. The final chapter is conclusions. It concludes the study findings, describes limitations, presents opportunity areas, and proposes next steps for the case company and that can be translated to other companies alike.

2 Literature review

This chapter is divided under two main headings: hospitals (2.1) and hotels (2.2). Both have identical structure. However, the contents are discussed from each of the industries perspectives. Firstly, in the beginning of each industry heading an overview of the industry is given. Next, the respective challenges and pain points are presented (2.1.1. and 2.2.1) This is followed by presenting the trends and technologies that have been identified in available literature (2.1.2 and 2.2.2). The final sections (2.1.4 and 2.2.4) summarize the key findings.

2.1 Hospitals

Hospitals are facilities that are a part of the healthcare industry, designed to deliver continuous services for complex and acute patient conditions. (Alpena Regional Medical Center, 2022) Hospitals are expected to be resilient and have the ability to scale their services in situations of emergency. Effective hospitals are well-designed and deliver against the needs of their users. They maximize clinical care delivery effectiveness and increase the comfort of hospital staff and patients. (WHO, 2022a)

In terms of building types, hospitals are the most complex. Hospitals comprise of a large variety of services and functional units. The wide variety of standards, regulations, and oversight affecting hospital development and operation reflect this disparity. Regardless of hospital size, location, or budget, all hospitals are expected to have specific characteristics. A hospital environment should be efficient and allow cost-effective operations. Distances across frequently used spaces should be minimized. Logistics systems should be efficient to allow the effective handling of waste, supplies, and food. (Carr, 2017)

Hospital environments can often be threatening and intimidating to patients, and this can impede recovery. Hospital buildings should be as comfortable as possible and patient stress should be minimized. Spaces should be easy to find and identifiable to allow the building users to navigate efficiently. Hospitals are also expected to be clean and sanitized. Security and safety measures should allow the protection of hospital assets, property, staff, and patients. Hospital buildings should also operate in a sustainable matter as they are heavy consumers of water and energy and yield excessive quantities of waste. (Carr, 2017)

2.1.1 Challenges and pain points in the hospital industry

The healthcare industry operates in a complex environment with a wide range of difficulties. These difficulties are due to both external challenges such as regulatory requirements, aging population, public and political demands, and internal such as employee shortages, resource limitations and, budget issues. (Siemens, 2022) This section presents some of the key challenges faced by hospitals globally that were found to be relevant to the study scope. The challenges are presented arbitrarily.

Employee shortage

WHO estimates that by 2030, there will be a shortage of 10 million healthcare professionals globally. (WHO, 2022b) Prior to the pandemic, there were concerns related to physician shortage spurred on by "normal" burnout, but the stakes have significantly increased since, and the reality has become tougher. (Harpaz, 2022) Today's clinicians feel overworked. Resources are being squeezed due to the severe global shortages of physicians, nurses, and midwives, leaving practitioners to cope with busy schedules, high expectations, and inconsistent support. (Elsevier, 2022) Studies have shown that there has been an increase in burnout, stress, and frustration among healthcare staff in recent years. (Vaisshalli, et al., 2022) Nurse shortages especially are creating additional pressure on the existing workforce. (Almendral, 2022)

Hospitals that are insufficiently staffed have shown higher rates of infections, mortality, and postoperative complications which are all major contributors to patient safety and quality of care. (Vaisshalli, et al., 2022) It is also projected that the continued labor shortage will significantly increase healthcare costs in the future. A lack of labor resources could hinder the development of individual health systems and increase the likelihood of access problems such as closures of facilities and longer wait times. (Fleron, et al., 2022) Healthcare professionals are warning that the sector is entering a critical phase without significant, structural transformation. (Harpaz, 2022)

Technology related risks and concerns

Covid-19 accelerated the move towards digital in hospitals, especially with the adoption of telehealth technologies. (Elsevier, 2022) However, while healthcare technology is rapidly evolving, hospitals are still hesitant to adopt new technologies. (Vaisshalli, et al., 2022)

Hospital staff and patients have concerns about software failures, which due to the nature of hospitals can have more catastrophic impacts than in any other workplace. Hospitals are also concerned about the higher probabilities of cyberattacks and data privacy issues associated with increased technology adoption. (Ravitz, 2020) Additionally, hospitals usually have unique needs that cannot be met with generic solutions. Moreover, strict regulatory, legal, and compliance requirements are creating challenges and slowing down the digital health revolution. (Ravitz, 2020) Other reasons for slow technology adoption include associated costs and perceived low amount of return on investment. (Ngafeeson, 2014)

The digitalization of patient health information, specifically Electronic Health Records (EHR) or electronic patient records, has been the focus of most investments in hospitals during the past ten years across many different countries. (Siemens, 2022) While patient information is mostly in digital form, clinicians feel that the growing amount of patient data is overwhelming. Clinicians now need to analyze data from multiple sources. (Elsevier, 2022) Increased adoption of technology makes it challenging to bridge the gap between data siloes. (Schiller, 2015) This is especially true in cases, where systems that are expected to exchange data are provided by different vendors. (Eastwood, 2022)

External requirements

Healthcare and hospital buildings are some of the facilities that consume the highest amounts of energy and water. This is due to the strict requirements for a healthcare-compliant and quality indoor environment. Hospitals require, for instance, sufficient, clean, and fresh air around the clock, a consistent power supply, different air pressure rooms, and a significant amount of hot water. (ARUP, 2021) Hospitals have different specialised areas that have specific requirements in terms of the indoor environment, cleanliness, water, power, and air filtration. These requirements are contributing to the intense use of resources such as water and energy. (ARUP, 2021) Due to this, this several nations now mandate that healthcare facilities incorporate energy-saving techniques to maintain their buildings sustainably. (Christiansen, 2019) Additionally, the rising energy costs are creating further challenges. (Bencharif, 2022)

Asset management

Healthcare facilities face unique challenges related to asset management. The healthcare industry handles enormous amounts of consumable inventory and various expensive assets.

(EZOfficeInventory, 2017) Clinical asset management issues are frequently due to the lack of a single centralized method for maintaining inventory. The precise amount of clinical assets in a hospital is therefore unknown. Asset management issues do not only relate to inventory visibility, but hospitals also lack visibility when it comes to knowing how many devices they have, how many of them are being used, and how frequently. Some devices are used on a daily while others might get used less frequently and some equipment might be left in storage unattended. According to TRIMEDX's polls, nurses can spend up to an hour per shift looking for equipment or checking its cleanliness. (Stevens, 2022)

Time is crucial in hospitals and having to track a lost asset can have a huge negative impact on a patient. Additionally, the condition of any asset in a healthcare environment is critical as it can directly impact the convenience and comfort of those using the facility as well as patient health and safety. (EZOfficeInventory, 2017) For instance, unplanned equipment shutdown can result in serious consequences such as medical complications and even loss of life. Additionally, equipment needs to be maintained in a cost-effectively and sustainably. (Christiansen, 2019)

2.1.2 Trends and technologies in hospitals

This section presents some of the key trends and technologies in hospitals identified in literature and that were found to be relevant for the study scope. These are presented arbitrarily.

Smart hospital concept

The concept of smart buildings has captured many industries however the technology’s biggest promise and rise is seen in the healthcare industry. (Chin, 2020) A smart building uses its intelligence to acquire helpful data from on-site user devices, sensors, systems, and services. By utilizing machine learning and artificial intelligence, a smart building can be programmed to respond to user and building manager needs. (Cisco, n.d.) IHS Markit | Technology projects that healthcare market will increase at a faster rate than the commercial market in terms of smart building revenue. (Barquin, 2020) The Data Bridge Market Research estimates that the smart hospital market will reach USD 147.5 Billion globally by 2029. (Data Bridge, 2022)

Smart hospitals and especially digitalization is seen as being the solution for mastering today's healthcare challenges. (High, 2020) It is seen that a smart hospital has the capabilities to simplify hospital workflows, help improve patient care, support with increased demands, and rectify today's deficiencies. (Rasoulian-Kasrineh, et al., 2021) The most predominant uptake of smart building technologies is seen in new healthcare buildings. It is expected that existing healthcare facilities will invest further to upgrade their infrastructures. The growth is driven due to aging population and high construction rates for new projects globally. (Barquin, 2020)

It is seen that smart hospitals will comprise of some of the following characteristics: automation, digital connectivity, and patient-centricity. Automation will be delivered with technologies such as RFID and barcodes. Processes such as pharmacy, food delivery and laundry will be automated. In a smart hospital digital connectivity will be leveraged to employ a standardized format for real-time data collection, storage, sharing and use. A patient-centric experience will be delivered with features such as automated cloud-accessible reports, telemedicine, and real-time monitoring of health data. (Regis College, 2021)

One of the core ideas behind smart hospitals according to Siemens, is the idea that technology-driven solutions shouldn't just be used to address specific issues; they should also be integrated with fragmented legacy systems and equipment to create an open ecosystem that generates substantial additional benefits. (Siemens, 2022) A smart hospital is a "building that is ready to unlock the value of data it generates". It uses common protocol to send data across its core systems either through a BMS or IoT sensors. (Thoughtwire, 2019) Hospitals may only profit significantly from digitization by connecting these systems together and making sure the data is accessible. (Siemens, 2022) Table 1 presents technology-enables use cases in a smart hospital. The table demonstrates how the integration of various systems such as IT, staff and building level technologies can deliver benefits.

Table 1 Technology-enabled use cases in smart hospitals (Siemens, 2022)

Technology	**Use case(s)**
Smart HVAC	Automatically adjusts based on patient preferences
RTLS	Allows asset tracking
Location tracking	Smart lighting helps track patient location and presence
Connected elevators	Allow predictive maintenance
Noise meters	Improve patients' sleep and decrease noise fatigue
Circadian lighting	Improve staff productivity and patient recovery
Smartphone	Staff can track patients and equipment Patients can control room settings (e.g., blinds, lighting, and temperature)
IoT-enabled lighting	Notifies which rooms are unoccupied

As shown in Table 1, a smart hospital uses technologies such as RTLS, for tracking and alerting staff on the location of patients and equipment. This improves the flow of patients and increases patient and staff satisfaction. Integration of systems such as shading, HVAC and lighting saves installation costs and allows patients to control their environment, thus saving time of staff and improving patient satisfaction. (Siemens, 2022)

Due to smart hospitals being a complex concept, there's no unified definition for it today. Many articles in which the smart hospital term has been used, have only implemented a smart tool in a specific area of the hospital environment. When considering that, a smart hospital is a much more expansive topic, thus it is difficult to pinpoint which hospitals today are truly smart. (Rasoulian-Kasrineh, et al., 2021)

Robots and automation

The evolution of AI has transformed the usage of robots in healthcare and robots are being used in clinical settings to enhance patient care and to support healthcare workers. The deployment of robots has especially increased during the Covid-19 pandemic. (Intel , 2022) It is seen that the adoption of robots will increase unprecedently due to their lowered cost and growing capabilities. (Fosch Villaronga & Gavriella Drukarch, 2021)

Cleaning robots accounted for a large portion of the demand for service robots in 2020 in the healthcare sector. Analysts anticipate that hospitals and other healthcare facilities will continue to place a high demand on the disinfection robot category because of ongoing

worries about Covid and labour shortages. (Condon, 2022) Additionally, during Covid, an increasing number of social robots were deployed to reduce the spread of Covid-19 by supporting healthcare staff with tasks such as patient monitoring. Social robots have been seen to be used with two central groups of people: the elderly and children to reduce the stress of patients and improve mental health. (Gonzalez-Gonzalez, et al., 2021)

Robots and automation are nowadays used to handle repetitive and manual tasks to free time for medical staff to focus on more meaningful tasks. (Intel , 2022) Robots can support in fields such as nursing care, rehabilitation, surgery, and logistics. A robot can, for instance, enable direct communication between medical staff and patients to enable remote care, transport goods and sterilize spaces. (Kwon, et al., 2022) They can assist in moving large objects like beds, patients, or other machinery, relieving some of the physical strain on healthcare professionals. (Condon, 2022) Robots help to reduce risks and streamline hospital workflows e.g., by independently prepping patient rooms, limiting patient-to-staff contact, and reducing the time to distribute medicine inside hospitals. (Intel , 2022)

Telemedicine

Since the World Health Organization announced the Covid-19 outbreak was a pandemic in 2020, many outpatient clinical visits were cancelled and in many cases, those were replaced with a new form of care delivery: telemedicine. (Wamsley E, et al., 2020) According to Fortune Business Insights, the global market size of telemedicine was 41.63 billion USD in 2019. The impact of Covid-19 globally has been astounding and the demand has witnessed a positive shock during the pandemic. (Fortune Business Insights , 2022)

Telemedicine means the usage of telecommunications technology for remote treatment and diagnosis of patients. During the pandemic, telehealth services were used to minimize exposure of healthcare professionals, staff, and patients and it was used as a tool for social distancing. At the time, it became apparent that numerous non-urgent conditions can be managed remotely. Additionally, telemedicine preserves healthcare resources, and transferring patients to telemedicine can increase the efficiency of healthcare delivery onsite. Using telehealth after a patient is discharged can result in fewer admissions, increased patient satisfaction, and decreased complications. (Wamsley E, et al., 2020)

In the future, telehealth can boost access to the necessary treatment in fields like behavioural health where there is a shortage, enhance the patient experience, and enhance health

outcomes. (Landi, 2020) The telehealth market was worth 50.14 billion USD globally in 2022 and it is estimated that by 2027 the market size will be 124.66 billion. Consequently, it is estimated that telemedicine will be more than just a pandemic trend. (Siwicki, 2022)

Real-Time Locating Systems

According to a report published by IHS, asset-tracking solutions or RTLS are among the most prevalent types of smart-building technologies being introduced in hospitals. (Chin, 2020) Location tracking and recognition services measure and monitor the location information of assets and people within a specific space by using short-range communication technology such as Wi-Fi, Bluetooth and RFID. (Kwon, et al., 2022)

The technology allows monitoring and tracking of assets such as medical supplies, pharmaceutical products, and medical devices in real-time which can improve the workflow of medical staff and logistics management. (Kwon, et al., 2022) RTLS is also used in hospitals to track and inform the nursing personnel of the whereabouts of patients. (Siemens, 2022) RTLS can also be used for safety measures. For instance, RTLS can prevent patients from wandering by providing alerts to staff thus, who can subsequently prevent the patient from wandering before any accidents occur. One RTLS provider, Civica, offers, for instance, sensor technology that integrates to access control doors. It can notify exit-seeking behavior to staff and sense when an at-risk patient is in an elevator and an elevator will be disabled to prevent it from leaving the floor. (Civica, 2022) RTLS can also be utilized to prevent theft by attaching RFID tags to expensive assets. Once an item passes a certain threshold an alarm can be raised. (Lorenzi, 2020)

Digital Twin technology

In recent years, digital twin (DT) technology has matured at a rapid pace, making it ideal for hospital environments. This technology has created enormous opportunities for addressing the major problems facing healthcare today. For instance, as hospitals are full of linked or connectable devices, integration can be achieved with a digital twin. (Prabowo, et al., 2022) According to Gartner’s 2022 Hype Cycle for Healthcare Providers, digital twins in healthcare is an emerging technology and it is estimated that the technology will gain mainstream adoption in the next 10 years. (Meyer & Jones, 2022) Gartner also predicts that by 2025, A formalized digital twin program will be a part of 25% of healthcare delivery organizations' digital transformation strategies. (Pessin, 2020)

A digital twin enables situational awareness which is at the core of any healthcare delivery organization. DTs are the physical manifestation of data obtained from the Internet of Things and other sources and used to build a precise digital representation of a real-world healthcare institution. (Meyer & Jones, 2022) It is seen that human middleware problems, interoperability problems, and problems with concealed or restricted data can all be solved with the use of Digital Twins. (Prabowo, et al., 2022)

Smart Hospital Digital Twins link up formerly siloed systems to give doctors and patients a broader perspective. Digital twins, in contrast to other solutions, take a comprehensive approach, considering every aspect of the hospital environment and merging data from many subsystems to deliver fresh perspectives in real-time based on interactions between people, processes, and IoT. With the help of IoT devices, AI/ML, and various other technologies, Digital Twins make it possible to examine data, workflows, patients, and physicians with a context-rich overview of the complete hospital environment. (Mcleod, 2020) Hospital administrators, physicians, and nurses can gain significant, up-to-the-minute insights into patient workflows and health by building a digital twin of the facility. (Prabowo, et al., 2022)

Digital twins offer a better means of assessing operations and alerting the appropriate people at the appropriate moment when instant action is required. They use sensors to monitor patients and coordinate equipment and employees. (Prabowo, et al., 2022) For instance, earlier patient transportation processes within a facility depended on considerably less transparent mechanisms. The systems lacked visibility into the porters' location, availability, anticipated arrival time, and other details. One of today’s leading digital twin providers for hospitals, ThoughtWire, offers features that enable, for instance, employees involved in a transport workflow to have visibility into who has accepted a transport request, what the transporters expected time of arrival, and whether extra equipment is needed and available for instance, a wheelchair. The workers can use an app to book transportation requests in, advance and even find the best routes to assets and places. (Mcleod, 2020)

Some obstacles to Digital Twin technology adoption are seen to be low data quality or a limited amount of available data points. Decision-making based on input from a digital twin is affected when data is incomplete or unreliable. Additionally, cultural obstacles exist, as there might be reluctance to trust the real-world representation that a digital twin provides. (Meyer & Jones, 2022)

2.1.3 Real-life examples of technologically advanced hospital buildings

This section presents some of the most technologically advanced real-life hospital environments today to gain insight into the potential future directions that the hospital landscape is moving towards. These examples were identified during the research process and have been described with some of the following statements: “most technologically advanced”, “best smart hospital” and “hospital of the future”. In addition to being unique from the rest, these hospitals also have some of the identified trends and technologies presented in chapter 2.2.1.

Humber River Hospital – Toronto, Canada

Humber River Hospital is being labelled as a “digital hospital”. (Zeidenberg, 2016) The facility includes robots, asset tracking, patient flow software solutions, wayfinding systems, and digitized patient records. All of the data from these systems are centralized into a single Command Centre, thus offering the staff greater visibility. Humber River also utilizes a BMS to optimize energy usage. (Chin, 2020)

Many of the operations at the Humber River Hospital were considerably redesigned with the help of electronic systems during the hospital’s modernization. The goal of implementing all digital systems was to improve patient care and increase productivity. Interoperability across all hospital areas was the biggest challenge. (Zeidenberg, 2016) To tackle this, the hospital used Information, Communication & Automation Technology (ICaT) to enable the hospital patients and staff with instant access to data. (Chenoweth, 2017)

The Command Centre which acts as a centralized data hub informs staff members around-the-clock, for instance, about patient influxes, which hospital units require more staff, the number of patients being treated, the demand and supply of beds, and the most urgent discharges and admissions. In practice, if a patient’s transport is requested and the transportation team is understaffed or busy with other requests the patient can be assessed for urgency by comparing all transport requests. The assessment allows the transport staff to then address requests based on urgency not only based on the order in which they have been placed. (HumberRiverHospital, 2022)

The hospital was the first in its country to deploy humanoid robots in healthcare. These robots have an interactive display and help the hospital visitors way find. The robots can

answer questions and share information. The humanoid robot was specifically adopted by the Child Life team to reduce the anxiety of children that usually occurs in the often-intimidating hospital environment. Its use has demonstrated positive results. (Humber River Hospital Foundation, 2018)

During modernization, the hospital doubled in size. The projection at the time was that nurses would walk around 11.6 kilometres a day in the new building, however, the hospital took step-saving measures and deployed Automated Guided Vehicles (AGV). These are robots on wheels that can move along corridors, open and close elevator doors, and signal people to move to the side. The robots can deliver up to 75 percent of supplies and save a plenty of steps. (Zeidenberg, 2016) The usage of robots also frees up time for the staff to focus more on patients. (Chenoweth, 2017)

The asset tracking solution, RTLS, also has step-saving benefits as it allows the assigning of the closest transporter to a patient instead of the one at the other end of the building. The RTLS has small tags attached to most equipment as well as staff and patients and allows a view into their location through a computer system. In a hostile or hazardous situation, the RTLS helps with security. The tags have a button that when pressed, calls security to the area. (Zeidenberg, 2016) The RTLS system also allows hospital visitors to track down their relatives during their stay at the hospital. (Chenoweth, 2017) The hospital also uses smart beds with sensors monitoring patient vital signs, in case of results that are outside the expected values the systems will trigger alerts, for instance, code calls. (HospitalNews, n.d.)

Nova Hospital – Jyväskylä, Finland

Nova Hospital is being labelled as the “smart hospital of the future” where the patient is at the center of everything. (BusinessJyväskylä, 2022) The project itself was Finland’s largest public investment in the area and the project was finalized in 2021 (SRV, 2020) (Sairaala Nova, 2020). The new hospital is the first large hospital to be built in Finland since the 1970’s thus allowing the architects to completely take a new perspective on the design of the building and move from old healthcare models to new ones. (FloorNature, 2021)

The old hospital was made up of several structures that were divided into four functional directions. These zones were successfully combined into one structure greatly improving the connections between various departments. (Rauta, 2021) The hospital was designed before Covid-19, however, already in the early phases of the hospital project the design included

pandemic wards that are isolated from the rest of the hospital both physically and from the perspective of air ventilation. (Granlund, 2022) Before moving into the new hospital, VR technology was used to help staff familiarize themselves to the building before entering the facility. The staff tested the hospital wayfinding signage with the VR model to guarantee easy navigation for both staff and guests. (Weatherley, 2020)

Nowadays the policy is to keep patients in hospitals for the shortest period possible. Thus, the hospital design focused on minimizing inpatient beds and improving the support care processes. The design phase included working with patients and their families to understand their pain points. It was discovered that patients find it difficult to orient themselves within large hospitals and find their way inside the building. Thus, the hospital used soft colours and natural materials to inspire homeliness. The newly designed patient rooms allow the patient to stay in the same consultation room for their entire visit and the staff is encouraged to move around the hospital to see patients directly in their rooms. (FloorNature, 2021) The hospital has received some criticism form the staff for not being able to achieve its goal of shortening the distances. (Heiskanen, 2020)

In the "smart hospital of the future", ICT and other solutions are used to enable staff to allocate more of their time to patient- and nursing-centered tasks. The task of the adopted technology is to assist with activities taking place in the facilities – automate routine tasks, eliminate errors, optimize processes, improve care and, make logistics more efficient. (Huld, n.d.) Lighting is managed with intelligent lighting systems that collect data and analyse it to deliver actionable insights. Lighting is monitored around the clock and the system sends notifications to maintenance personnel in case of any faults. Other equipment is also integrated with the same technology, enabling maintenance teams to locate the exact location of a faulty asset, thus saving them a significant amount of time. Each space of the building is also equipped with occupancy sensors to provide data on how the building is used. These insights can provide a better understanding of the efficiency of the facility and translate to lower costs, energy savings, and improved utilisation rates. (Helvar, 2021)

Johns Hopkins Hospital – Baltimore, Maryland, United States

The Johns Hopkins Hospital features many advanced technologies such as an automated waste and supplies transportation setup that operates underground and a high-tech staff- and equipment locating system. (Staff Writers, 2022) The building uses an advanced air

circulation system to prevent the spread of germs. (Johns Hopkins Medicine, 2022a) In addition, the Johns Hopkins Hospital has a dedicated application to help patients and visitors find their way by navigating them to the hospital, helping them locate and save their parking spot and getting clear directions to their appointments (Johns Hopkins Medicine, 2022b).

The Johns Hopkins Hospital is also argued to be the first hospital to deploy a full-scale Command Centre. More than 20 digital screens are lined up along the walls of the 5,200-square-foot building, and dashboards are added to each of the screens to give staff members access to real-time data. (MedTech, 2018) The Command Centre provides situational awareness as staff members get access to predictive and real-time information and are guided to take action to resolve and prevent bottlenecks, reduce risks, coordinate services, and reduce patient wait times. (Johns Hopkins Medicine, 2016) Increased hospital capacity was the main issue the Johns Hopkins Hospital initially attempted to solve with the Command Centre, and it has since significantly improved its capacity and workflow efficiency since the system's implementation. (MedTech, 2018)

2.1.4 Summary of hospital section

Chapter 2.1.1 presented some of the key challenges and pain points faced by hospitals today based on the available literature. Chapter 2.1.2 presented key trends and technologies in the hospital sector based on available literature. The outcome of this chapter was five trends/technologies that have been emerging and are seen to have prominent opportunities in the future. Chapter 2.1.3 presented three examples of today's most technologically advanced hospitals that were also found to represent the findings from chapter 2.1.2. This chapter also gave more practical examples of how these emerging trends and technologies are visible today. The following list summarizes the key findings from chapter 2.1.

Challenges and pain points

- Resource shortages, especially shortage of healthcare workers resulting from increased burnout and frustration amongst healthcare staff as they are forced to cover gaps and thus focus less on tasks that meet their level of skills.
- Healthcare technology has evolved rapidly, however technology adoption is still slow in this industry compared to others due to concerns around software failure,

cyberattacks, data privacy, compliance, and legal regulations among others. Additionally, technology that exists today is operating in data siloes.

- Hospitals consume large amounts of resources such as energy and water. Hospitals are facing challenges to reduce energy consumption due to sustainability mandates and rising energy costs.
- Hospitals handle large amount of inventory and other assets and lack visibility into the location of assets, their usage and condition.
- Critical equipment failure can have significant impacts on patient care.

Emerging trends and technologies

- Smart hospitals are seen as a concept for mastering today's healthcare challenges. The most prominent uptake of the concept is estimated to be in new hospital buildings. Smart hospitals will use various technologies to automate and improve the patient experience. The key characteristic of a smart hospital will be interoperability of various systems. Nova hospital has been labelled as 'smart', as it has automated many routine tasks and uses smart IoT solutions, to support e.g., equipment maintenance activities and to reduce energy consumption.
- Digital twin technology was identified to be an emerging trend in hospital environments, although the technology was not acknowledged in the reviewed real-life examples. DT technology is seen to tackle many of today's challenges in the hospital setting such as lack of interoperability among different systems. It is estimated that DT technology will become mainstream in the future. A digital twin relies on a certain level of technology adoption, especially IoT, to enable a digital replica of a physical healthcare environment. Thus, one of the obstacles for digital twin adoption are limited amount of data points. However, based on the literature review, hospitals are actively adopting IoT.
- The usage of robots has increased due to the pandemic, and it is seen that the technology's adoption will increase tremendously in the future. The technology can help support challenges stemming from labour shortages by assisting healthcare staff and improving hospital workflows. For instance, Humber River Hospital uses

humanoid robots to reduce the anxiety of children, to support with logistics and wayfinding.

- Wayfinding was also deemed important in the Johns Hopkins Hospital in the US, as they have deployed a wayfinding application for their patients and visitors to use.
- The demand for telemedicine has increased significantly during Covid-19 and it is seen that it will be more than just a pandemic trend due to its capabilities of preserving resources and increasing patient throughput. Humber Rives Hospital uses sensor solutions to remotely monitor patient vital signs.
- RTLS is one of the technologies that is most prevalent in the hospital environment. It is used to track people and assets. Humber River Hospital uses RTLS to reduce the amount of walking for nurses and to enhance the security of staff. RTLS is also used at Johns Hopkins Hospital.
- Hospitals are expected to have efficient logistics systems for handling waste, supplies and food. Johns Hopkins Hospital uses an underground waste and supply system to make logistics more efficient.
- Maximized cleanliness and hygiene are some of the key characteristics of a hospital. Johns Hopkins Hospital is using an advanced air circulation system to reduce risks of contamination.

2.2 Hotels

The essence of the hospitality industry is to serve guests. Guests expect to be treated with warmth and provided with the best service. At the heart of the hospitality industry is offering comfort for the visitors who are in a new place. Hotels are one sector of the hospitality industry. (Nain, 2018)

Every hotel's objective is to maximize profitability; thus, it must focus on boosting revenues and cutting expenses. The two most important metrics that determine a hotels profitability are occupancy rate (OR) and Revenue Per Available Room (RevPar). While accommodation revenue usually forms the largest part of hotel revenue, most hoteliers are starting to provide

new services. TRevPar is therefore another performance indicator used by hotels to consider total hotel revenue not just that from accommodation. (Lima Santos, et al., 2020)

2.2.1 Challenges and pain points in the hotel industry

This section presents some of the key challenges faced by hotels globally that were found to be relevant to the study scope. The challenges are presented arbitrarily.

Changing guest expectations

In modern times, humans are completely dependent on technology. Although we in some ways expect to disconnect from some areas of our lives during a vacation, we still expect to be connected. Wi-Fi connection was one of the first guest demands in hotels, however, now it is a fundamental requirement. (Nain, 2018) More and more visitors are utilizing their mobile devices for a variety of tasks. (Skift; Oracle, 2022) The rise of smartphones and social media, along with technological luxuries such as hotel room technology and AI chatbots increase the likelihood that future travellers will have considerably greater expectations for the hotel sector. (Amadeus, IHG, 2019) A survey conducted in 2017 by the Oracle Hotel, found that customers are more likely to interact with hotels that provide advanced technologies if the guests feel they are in control of the experience. (Skift; Oracle, 2022)

The modern traveller has changed, and as a result, many hotels are struggling to keep up with changing visitor preferences and expectations. (REVINATE, n.d.) A hotel is judged by the level of service. Key factors that contribute to this are attentive and skilled staff, comfortability for guests, and a personally tailored experience. To repeat customers and generate loyalty among customers, hotels need to understand the customer types they want to attract and provide facilities and services that meet the needs of their target customer base. (Nain, 2018) It is seen that customers will become more central in the hotel sector – technology will be used to offer personalized offers, drive loyalty and improve marketing alongside the evolution of Customer Data Platforms. (Duetto, 2022)

Sustainability

There is increasing pressure on hotel businesses to prioritize sustainability, this is driven by several factors. Hotel customers today are putting more emphasis on choosing their stays based on the hotel's environmental policies. (Hotelier & Hospitality Design Magazine , 2022) According to a 2018 survey by Hilton, 33% of travellers look into a hotel's environmental and social policies before making a reservation, and 44% of travellers under the age of 25 do so. (Touryalai, 2018)

Hotel investors are seeing hotels that rate high on the Environmental, Social, and Governance (ESG) framework as more attractive investments. (Hotelier & Hospitality Design Magazine , 2022) The Environmental aspect refers to measures around waste reduction, energy efficiency, and water conservation (Hotel Tech Report, 2022). This shift is already taking place in the US and expanding quickly in Europe. (Hotelier & Hospitality Design Magazine , 2022)

Furthermore, energy costs are on the rise in most economies. One of the biggest contributors to hotels' running costs is utility and energy. (Nain, 2018) Hotels and restaurants will find it much more difficult to balance their budgets if they do not take action to minimize their energy use or discover alternative energy sources. (Hotelier & Hospitality Design Magazine , 2022) It is seen that reducing energy consumption will become one of the top priorities for hoteliers. (Nain, 2018)

Additionally, many hotels are housed in old structures. Despite several exterior and interior renovations, hotel real estate is not up to date with contemporary standards, such as being energy efficient or self-sufficient. According to The Hotel Pulse-Taker, many hotels lack computerized building management systems, precise energy measuring systems (water, CO2), and recycling facilities. In addition, hotel buildings are large consumers of water and power. Especially, older city hotels have a competitive disadvantage compared to recently completed hotel real estate projects. (De Peuter-Rutten, n.d.)

Employee shortage

In 2020, hospitality companies were forced to reduce services to cut costs due to historically low demand, which resulted in severe employee reductions. (Wendt, n.d.) The staffing shortage is still a visible challenge, for instance, both in the US and Europe as many jobs remain unfilled (Wadhva, 2022). The unfortunate fact is that the hospitality industry was impacted considerably harder than other industries by Covid-19, which is one of the reasons

for the labour shortages. Many of the employees who were laid off or given furloughs found work in other industries. It is seen that travel will continue to pick up and squeeze even the most efficient properties to their limits. (Skift; Oracle, 2022) As travel levels continue to rise, the staffing challenge is impacting hotel operations in many ways. Some hotels have had to limit occupancy because of the low availability of staff to clean rooms. Additionally, hotels are having to compromise on offered services and the number of amenities. (Wendt, n.d.)

Technology is seen to be a critical element to consider in the future when hotels are aiming to scale their efficiencies and fill any gaps. Even when considering attracting new employees, technology is seen to be a selling point. A survey conducted by Oracle and Skift shows that executives are aligned with the opportunity technology can provide to attain new staff as nearly two-thirds of the survey respondents mentioned technology adoption would be of help. (Skift; Oracle, 2022) A survey by Harri and CGA has revealed that hospitality employees or individuals with recent experience from the hospitality sector see the importance of technology to improve employee experiences as well as think their employers could better utilize technology (Harri & CGA, 2022). It is seen that staff efficiency strongly correlates with guest experience, thus at the highest priority are technologies that streamline staff operations such as mobile technologies, contactless solutions, and automated messaging. Offering visitors, the choice of contactless check-in and mobile messaging not only generates chances to meet guests where they are but also mitigates the effects of staffing shortages and develops a future service model that is more effective. (Skift; Oracle, 2022)

2.2.2 Trends and technologies in hotels

Personalization

Hotels are aiming to create more personalized experiences by leveraging guest data and learning guest preferences, likes, and dislikes in response to changing guest expectations. (Nain, 2018) (Trivago , 2018) Data about hotel guests helps establish a comprehensive understanding of each visitor, from their interests to their temperament. In turn, this encourages attentive interactions and a uniquely memorable experience. Combining data allows brands to forecast and address customer demands. (Amadeus, IHG, 2019)

As an example, Marriott is utilizing a digital platform that gathers all guest data into a single guest profile. (Bova, 2018) The Single Guest Profile serves as a single source of truth. It's where all the information available on a guest (from different booking engines, transactional systems, Food & Beverage platforms, PMSs, etc.) is matched, providing a single 360-degree overview of the guest. (For-Sight, n.d.)

Marriott is using the data to provide personalized service. Marriott gathers for instance guest flight data that enables them to know whether a guest might be jet-lagged or their flight delayed. This consecutively allows them to better serve their guests, for instance, by offering them comforting amenities upon their arrival. This system allows the hotel staff to know the guest's different leisure hobbies, for instance, if the guest has a preference for jogging, the hotel staff can provide the guest with potential routes that they might want to explore. (Bova, 2018)

In the future, context will be highly relevant, and it is expected that personalization will happen more in-the-moment. Personalization will consider guests' physical and emotional states, as well as monitor guest behaviour. Hotel staff will have the ability to respond accordingly in real-time and use contextual data, for instance, gathered online that can be used to indicate guest preferences. (Amadeus, IHG, 2019)

It is predicted that contextual data will be gathered from multiple companies and shared inter-industry followed by trans-industry, and data will be less siloed amongst companies thus allowing a holistic view of each guest. However, it is yet to be seen, how guest data can be gathered in a matter that does not compromise guest privacy. (Amadeus, IHG, 2019) As hotels collect a lot of information and data about their guests, hotels are popular targets for hackers as a leak could result in thousands of personal data, for instance, names and social security numbers being compromised. Thus, making data security and privacy a key concern for the hotel sector. (Nain, 2018) It is seen that in the future, hotels that encourage data exchange will use partnerships in a way that hotels will no longer store data but access it. (Amadeus, IHG, 2019)

Automation

The demand for automated services is growing rapidly in the hospitality industry. Hotel automation is quickly becoming recognized as a vital tool for success, especially for hotels located in competitive regions, according to market survey research by Duetto, a provider of

hospitality applications. (Duetto, 2022) The transformation of manual, labour-intensive tasks and routines into automated processes is known as automation. (Campbell, 2022) Automated services are a great solution for repetitive tasks that demand more staff time and effort than is necessary. Automating routine requests can allow hotel staff to offer more direct, one-on-one service whenever necessary and give them the expertise to create more personal and meaningful relationships with guests. (Skift; Oracle, 2022)

Self-service is a form of automation that has been seen to rise in the hotel industry as it provides more convenience and does not need support from employees. Guests can, for instance, perform check-in and check-out by themselves. (Dalgic & Birdir, 2020) Some hotels also use their own branded applications to provide seamless experiences to their guests, in-room voice control, or tablets within rooms to allow guests a more personalized and efficient experience. (Sbounias, 2019)

It is seen that many visitors appreciate the level of automation where they can check in, head to their room, text for assistance, and then exit the premises without ever talking to anybody else or the hotel employees. In a survey conducted by Oracle and Skift, about 26% of travellers indicated that they "strongly agree" that they would be more likely to book a stay at a hotel that offered self-service technologies to reduce interaction with other people. This pattern also emphasizes the demand for contactless technology and user-friendly digital amenities that visitors are accustomed to from their homes. (Skift; Oracle, 2022)

Other forms of technology that enable automation are robots and AI. Nowadays many hotels have deployed robots to carry out tasks that are normally handled by humans and their work includes the tasks of a receptionist, housekeeper, and concierge. For instance, hotels are using robot butlers for delivery tasks. These robots can transport linen, toothbrushes, and other amenities from room service to guests and can navigate autonomously within the hotel hallways and elevators. Robots are also used to notify housekeeping when there are, for instance, empty food trays in the hall. Robots are also being used for entertainment purposes, preparing drinks, and food and improving the guest experience. Robots are also being used to help customers with their problems and support in attracting new customers. (Boley, 2020)

AI technology is also used increasingly with chatbots that can handle customer requests around the clock. (Boley, 2020) It is argued that automation in some form is essential to scale services while the number of guests grows. However, even in the relatively near future,

the ability of automation to unlock "beyond human"-levels of customer service will be central. These levels could range from satisfying basic customer service requirements, personalization choices, and robot concierge, to guest recognition, information retrieval, and access to detailed service options. (Amadeus, IHG, 2019)

Contactless guest journeys

One of the current trends in the market is contactless, and in many ways, it was accelerated by the pandemic. (Skift; Oracle, 2022) These technologies facilitate, for instance, contactless check-in and check-out which allows guests to pass the front desk. (Psycha, 2021) (Hollander, 2022) Some companies have developed new contactless methods during the pandemic, for instance, gesture-controlled elevators to reduce physical contact with the elevator button surfaces and maximize cleanliness. (Ziraknejad, 2022) Contactless payment methods, especially mobile wallets such as Android Pay and Apple Pay are being adopted widely as a means to reduce touchpoints. (Boley, 2020)

Another form of contactless technology that is becoming very common, is digital room keys that are integrated into guests' smartphones. Guests can use their smartphone to unlock doors using, for instance, Bluetooth technology. Digital keys provide greater security for guests by allowing only authorized users to access locked areas. Additionally, when access control is contactless, this makes the process more hygienic. Deploying digital room keys also means reduced costs for hotels. (Psycha, 2021)

A survey by the Oracle hotel found that over half of the travellers who responded would like to see contactless technologies be permanently adopted in the next three years. Additionally, hotelier executives have said that contactless services are one of the most likely features that the industry will be adopting. Only 3.7 percent of the executive respondents said that they are not planning to adopt contactless technologies, while the rest have already heavily invested or are in the early stages of adoption. (Skift; Oracle, 2022) It is seen that contactless will be staying, however, there will still be guests who prefer a traditional touch experience. (SHIJI, 2022)

In-room smart technologies and IoT

The development of the internet has created immense amounts of opportunities for hotels to enhance the in-room guest experience while simultaneously raising guest expectations. The first innovations were in-room tablets. However now the in-room experience has switched

to voice-controlled assistants that allow personalization of the in-room experience as well as the proliferation of applications that run on the guests' own mobile devices. (Zabin, 2018a)

The trend of enhancing the guest experience and giving them more control has resulted in a multitude of new solutions on the market. One is Alexa Smart Properties for hospitality by Amazon, a voice-controlled digital concierge that integrates hotel services and amenities aiming to simplify guest tasks. The guests can, for instance, call the front desk, check out, order room service and play music. (Adelman, et al., 2021)

A hotel in Mexico City has adopted smart toom technologies that allow guests to control the TV, room lighting, temperature, windows, and shades with their smartphone. The room's entertainment system allows access to popular streaming platforms. The system does not require its quests to download any application, log in or even join the hotel's Wi-Fi system, to access these smart features guests need to pair with the TV to get control over their entire in-room experience. (Hotel Technology News, 2020)

IoT adoption rates are expected to rise higher as hoteliers work to stand out in an increasingly competitive market now that a big portion of the industry has recovered and is welcoming back visitors in large numbers. (Patrick, 2022) Some of the use cases for IoT usage in the hotel industry today include location-based data gathering, where technologies such as Bluetooth and GPS are used to gather data on guest locations to advertise services nearby. (R, 2022) Other IoT solutions serve as occupancy sensors that allow minimizing of in-room temperature when guests are not in the room, to lower energy consumption. (TELE2, 2022)

Technology integration

While the demand for new technology rises, so does the number of technology partners/vendors, service providers, and distributors. The hotel industry is at a point of technological expectations crossroad while the core goal of a hotel remains the same – having a profitable business, delivering excellent guest service, and ensuring that the guest returns to your hotel on their next travel. (Schaap, n.d) Any seasoned hotelier knows that data integration and technological interoperability are crucial for streamlining hotel operations and promoting ongoing performance improvement. The enemy of hotels looking to streamline operations and provide a great guest experience are fragmented solutions and data silos. (Zabin, 2018b) More industry executives are paying attention to technology

adoption and upgrades, as well as building an integrated tech stack, both at property and enterprise levels. (Duetto, 2022)

It is seen that due to the number of hospitality technology vendors, many providers have now started to provide open APIs, whereas traditionally the data has been kept siloed. (Schaap, n.d) It is argued that the demand for API services will increase significantly over the next several years as more hotels attempt to develop the precise technology stack that suits them. (HotelTechReport, 2022) Open-source APIs are seen to be the future, as the hospitality industry requires multiple different technology vendors. Platforms should integrate and work well with other systems if they want to gain market share. (Amadeus, IHG, 2019)

2.2.3 Real-life examples of technologically advanced hotel buildings

Several hotels are leading the way and disrupting the industry with their exceptionally innovative use of technology. This chapter presents three real-life hotels that stand out from the rest and have been described with some of the following statements “futuristic”, “most technologically advanced” and, “the world’s first… []”. In addition to being unique from the rest, these hotels also validate the identified trends and technologies presented in chapter 2.2.1 and give insights on the potential future directions that the hotel landscape is moving towards.

Sinclair Hotel – Fort Worth, Texas, US

The Sinclair Hotel building was built in the 1930s and went under renovation in 2015, opening its doors again in 2019 (Sinclair, 2022) (Temblador, 2019). The Sinclair Hotel has since been labelled as an “iconic hotel redesigned for the future” and it has deployed digital elements in nearly every facet of the building. The hotel rooms are equipped with Smart Mirrors - interactive mirrors embedded with touch screens. The Mirrors act as digital concierges. They allow the hotel guests to sync the mirrors with the room’s TV or other applications and watch news or movies. They provide the users with information on weather, hotel services, check-out times, and local attractions. (The Hotels Network, 2021) The hotels’ lights, window coverings, smart mirrors, and minibars are powered with power over Ethernet (PoE) technology. Every cable going to a light fixture, minibar, or smart mirror

transmits data in addition to power. The Ethernet system allows the hotel to detect, for instance, when a lightbulb fails subsequently notifying the proper employees. (Hasek, 2021)

Each guest room uses Bluetooth occupancy sensors. (Danielsen, 2020) With their presence-sensing features, the hotel can optimize its energy usage. The same technology allows the guests to control the room environment. (The Hotels Network, 2021) This technology is also utilized by housekeeping, as they have access to data that tells them whether guests are in the room or not, thus reducing unnecessary disturbance for guests. The Bluetooth sensor technology also has the potential to do people counting. It gives the Sinclair hotel the ability to gather data, for instance, on how much a conference room is used and adjust AC and therefore reduce energy costs. Whenever someone steps back into the room the HVAC system can adjust the temperature back to a comfortable level. (Aslam, 2021)

The hotel is also experimenting with location analytics. If the guests' mobile phones are turned on, the building's entry points can automatically match the cell phone number to the occupant as they arrive. (Danielsen, 2020) This allows the reception staff to identify registered guests and greet them by name upon arrival. (SAS Software, 2020) Another example is when a guest steps into the hotel bar they can be detected by their mobile phone and receive a personalized greeting to their phone and an offer to get a discount off their favourite drink based on previous purchase data saved into the hotel systems. (Aslam, 2021)

The Lake Nona Wave Hotel - Orlando, Florida, US

The Lake Nona Wave Hotel opened its doors in 2021. (Nunez, 2022) The hotel is being labelled as "the most technologically advanced hotel in the world". It aims to provide personalized, technology-based experiences to its guests. One of the partner companies of Lake Nona Wave hotel has deployed its guest experience and staff management platform. The provider has equipped the hotel with guest-facing features such as a branded application that features mobile check-in, digital room keys, and guest messaging. Guests can check in before their arrival, order room service, and make reservations with the mobile application. The back house system enables the hotel to streamline their service, gain business insights, and better communicate with their guests, with the guest messaging feature allowing a more tailored guest experience. (OKKAMI, 2022)

The hotel uses Smart Windows which utilize AI technology to regulate room temperature based on outdoor conditions without needing traditional window blinds. (Lake-Nona, 2020)

This allows the hotel guests to enjoy their experience at a comfortable temperature. Reportedly Smart Windows help their users sleep more and reduce stress and anxiety more than traditional windows with blinds. (Lake-Nona, 2022)

The guest rooms use smart bed technology that adjusts automatically to optimal sleep conditions. The smart beds have mattress temperature control and a rebalancing feature that helps eliminate pressure points. The hotel uses UVC air sanitization and circadian lighting to improve sleep, guest performance, and breathing conditions and is the world's first hotel to install a VR-enabled meditation system. (Poitevien, 2021) Food and beverages are delivered by a robot butler. (LiveAuctioneers, 2022)

FlyZoo Hotel – Hanzhou, China

FlyZoo hotel by Alibaba is a "futuristic" hotel launched in 2018, with many high-tech tools adopted with the aims to cut labour costs and to reduce the need for staff-visitor interaction (ESC Editorial Team, 2019) (Srivastava, 2019) The hotels' concept is an experiment to test the comfort level the guests have for using unmanned services. The hotel employs humans for cooking, cleaning, and reception tasks. However, food delivery is handled by service robots. Guests can order food from their mobile phones. Additionally, a robot arm is used at the bar to prepare drinks and cocktails. (Srivastava, 2019)

The room has voice control that allows guests to control their in-room environment – adjust the temperature, curtains, lighting and, access room service. (Srivastava, 2019) Guests can access their rooms with the use of facial recognition technology or traditional room key cards. (Staff, 2019) Facial recognition is also used for elevator access management. By identifying themselves in the elevator, the guests can use the elevator to take them to their floor. (Altexsoft, 2021). The hotel uses photos taken in the reception during check-in to verify the users are guests of the hotel. (Staff, 2019) The facial recognition system compares the guests' faces to the pictures taken during check-in. (Staff, 2019) To make guest movement inside the premises as efficient as possible, an elevator is automatically ordered to the guests' room floor when they exit their rooms. (Tanoko, 2019) The facial recognition systems' data is erased automatically from the system once guests check out, which they can do by using a button in an application. By pressing the check-out button, the guests' access to the room is automatically revoked and the bill is charged through Alibaba's online wallet. (Srivastava, 2019)

2.2.4 Summary of the hotel section

Chapter 2.2.1 presented key challenges and pain points faced by hotels today based on the available literature. Chapter 2.2.2 presented key trends and technologies in the hotel sector based on available literature. The outcome of the chapter was five trends/technologies that have been emerging and are seen to have prominent opportunities in the future. Chapter 2.1.3 presented three examples of today's most technologically advanced hotels that were also found to support the findings from chapter 2.1.2. This chapter also introduced more practical examples of how these emerging trends and technologies are visible today. The following list summarizes the key findings from chapter 2.2.

Challenges and pain points

- As travel levels continue to rise, many hotel operations are impacted negatively as supply is not able to meet the levels of demand due to global staffing shortages resulting from the pandemic.
- Guests are expecting more control over their hotel experience with the utilization of technology. Hotels are struggling to keep up with changing guest expectations and preferences.
- External sustainability demands and rising energy costs are creating pressure for hotels to prioritise environmental initiatives. It is estimated that minimizing energy consumption will become a top priority for hotels.

Emerging trends and technologies

- To better service their guests, retain them and drive loyalty hotels are aiming to create more personalized experiences by utilizing data gathered from different hospitality systems. The Sinclair Hotel provides advanced personalization through targeted marketing and guest identification/detection technologies e.g. mobile devices. FlyZoo Hotel uses smart technologies to land an elevator to the guests' hotel room floor automatically when they leave their room.
- Demands for technologies that enable automation are growing as they relieve challenges resulting from the pandemic. Hotels today have adopted self-service guest technologies, and robots to automate delivery tasks. Adopting contactless self-

service technologies are a top priority for hotels. Lake Nona Wave Hotel has deployed a mobile-based guest journey with mobile check-in, check-out, and mobile room keys. FlyZoo hotel uses robots to automate room service delivery.

- More hotels are adopting in-room smart technologies to allow guests more control over their environment and to minimize energy usage. Sinclair hotel in the US has equipped its hotel rooms with smart sensors to save energy, and smart mirrors that act as digital concierges. Lake Nona Wave Hotel uses smart windows that help regulate room temperature. FlyZoo Hotel allows its guests to control their room environment with voice control.
- The proliferation of systems and technologies in hotels is rising. To leverage seamless data flow hotels are utilizing APIs.

3 Empirical findings

This chapter presents the interview data collection process and its findings. As mentioned in chapter 1.4 the primary research method used for the study was interviews. The key objective was to gain an external view by interviewing other company experts, however, to keep a rational view of the company a few internal interviews were also conducted.

The interviewees were divided into two groups: internal and external experts. The first interviews were conducted with the case company's internal industry experts. The second phase of interviews was with external experts – representatives of companies that act as service providers for the selected building segments: hospitals and hotels. Section 3.1 presents the interviewees and their selection process. Section 3.2 presents hospital findings and 3.3 hotel findings.

3.1 Data collection

This chapter describes the methods used for the interviews. The total amount of interviews was nine. Three internal expert interviews and six external interviews. Three of the external interviews focused on the hospital sector and three focused on the hotel sector. Table 1 lists the details of each interview.

Table 2 Interviewees

	Nature	Participant / Role	Segment	Date, length	Documented as
1	Internal	Head of Technology Strategy, Customer and Competitor Intelligence	Hotels and hospitals	16.06.22, 45 minutes	Field notes and recording
2	Internal	Head of Key Account Management	Hotels and hospitals	08.07.22, 45 minutes	Field notes and recording
3	Internal	Senior Business Development Manager, Smart Buildings	Hotels and hospitals	12.07.22, 45 minutes	Field notes and recording
4	External	Business Development Manager, Automation and Robotics	Hospitals	27.07.22, 45 minutes	Field notes and recording
5	External	Director, Technical Sales and Business Consulting	Hospitals	16.07.22, 45 minutes	Field notes and recording
6	External	Manager of Healthcare Solutions	Hospitals	26.08.22, 45 minutes	Field notes and recording
7	External	Director of Product Integrations and Partners	Hotels	14.10.22, 45 minutes	Field notes and recording
8	External	Senior Vice President	Hotels	4.11.22, 45 minutes	Field notes and recording
9	External	CEO	Hotels	3.11.22, 45 minutes	Field notes and recording

The internal interviewees were selected based on their expertise and knowledge about the research topic. These focused on both hospitals and hotels. The external interviews consisted of six interviews where there were representatives from five different companies. The companies that were included in the interview scope were selected together with the case company from a list of candidates that was gathered during the beginning of the thesis project.

Candidates were gathered using two approaches: 1. suggestions made by internal interviewees 2. companies that were found during the research process and were relevant to the study. Numerous candidates were gathered out of which the most fitting ones were

contacted first. Based on the number of accepted invitations more candidates were contacted to reach a comprehensive amount of interviews.

Candidate companies were selected based on different factors such as service offering, company size, customer types, and market location. The list of candidate companies was categorized based on the type of services they provide for the specific industry/segment to avoid selecting interviewees from companies with offerings too similar. Selecting companies that operate in a limited or small geographical area was also tried to be avoided to achieve more of a global perspective. The interviewees were selected based on their role in the company. The interview questions can be viewed in appendix 1.

3.2 Findings – Hospitals

What pain points and challenges are hospitals facing?

The interviewees highlighted staffing and resource shortages. Interviewee 6 highlighted it to be the biggest challenge faced by the healthcare industry today: *"The biggest challenge today that was exacerbated by the pandemic is the staffing and resourcing challenge. Physicians, clinicians, allied health, and support staff are all stretched to their limits trying to cover the immense gaps left by increased burnout, shortage of staff, poor resource management and more. This pain point is a 'Wicked Problem' that precedes almost all other challenges and pain points that hospitals and healthcare environments face."* It is seen that this challenge is affecting the day-to-day operations and efficiency of hospitals.

The interviewees also highlighted how clinicians are performing tasks that could and should be eliminated or automated. Examples of these activities are pushing the trolley, and time wasted on finding things such as wheelchairs and other medical equipment. The interviewees mentioned how it is quite common in hospitals to lack visibility into the location of hospital equipment. Furthermore, it was seen that this affects the utilization rate of equipment as well as makes hospitals easier targets of theft.

One of the interviewees mentioned traditional hospital building designs as a pain point: *"Movement inside hospitals is a pain point due to long distances, for instance, the hallways are long"* (Interviewee 5).

Interviewee 2 mentioned equipment shutdown as a pain point: "….*one elevator down and people with the wheelchair cannot get on. So, it's a critical part of any hospital especially when you have like the beds going inside. So, if the elevator was not working, you cannot really move around so it is so critical."* Unexpected equipment shutdown can create significant delays in hospital processes and ultimately affect patient care negatively.

Not only does equipment downtime affect workflow efficiency but so do any inefficiencies that involve people and asset flow within hospitals:

"People flow is critical in a hospital" (Interviewee 2).

"So, asset tracking is a big issue in hospitals because they have so many so much equipment and supplies, materials like medicines and stuff like that, that they need to keep track of. It's typically a very big building and sometimes you need a material in one room, and it's located somewhere else. Maybe nobody, knows where it is" (Interviewee 1).

Interviewee 6 highlighted the impact that delays in clinical workflows can have: "*There are many processes in the hospital that a matter of seconds actually matters. But I talked about the code event this is one where everything is very time sensitive. If you can get the right people, there even 10 seconds faster. That increases the chances of being able to save this patient's life. So, there are many situations where even these micro units of time have a significant downstream impact to what is actually happening for the patient"* Interviewee 6 is referring to code calls, especially code blue calls that require immediate support for the patient.

Another challenge was mentioned by interviewee 6: *"The proliferation of healthcare technology over the last 10-20 years has created an ecosystem full of disparate and single-purpose solutions. What has now happened is that healthcare organizations have a combination of 'best-in-breed' solutions or in-house custom build solutions to try to piece together an enterprise level orchestration"* Interviewee 6 is referring to how the lack of standardization and increased adoption of different systems is creating a problem with interoperability. The adoption of IoT technologies was mentioned as being one of the healthcare technologies of which proliferation has further increased the gap between different solutions.

What trends and technologies are emerging in the hospital-built environment?

Interviewee 6 mentions how the hospital technology landscape is transforming: "*EMRs and Nurse call systems exist in nearly every hospital now however, there has certainly been an increase in 'smart' healthcare tech emerging. IoMT (Internet of medical things), sensors, remote monitoring... devices that serve as an extra set of eyes and ears for clinicians have been widely accepted."*

One smart healthcare solution that was repeatedly mentioned by several interviewees was people and asset tracking systems: "*Real time locating services or real time locating systems that allows staff in a hospital to search for things like IV pumps, wheelchairs as well as people such as patients, doctors or nurses"* (Interviewee 3).

There are several use cases for these systems in today's hospital environments:

"It can be to monitoring patients who have dementia, for example, who are not allowed to leave a room. So, when they do leave the room like via a virtual geofence right, an alarm will be sent directly to the nurse. Or the same goes for a wheelchair. We talked about stolen items, so whenever your chair, leaves the hospital, then an alarm would be sent for example to security team" (Interviewee 3).

"In hospitals you want to ease when people go to the see the patients or patients have to find a room. At the same time, you have lots of things going on in the hospital. There are cleaning people, people transporting. Asset management solutions are there from IoT companies. So, it's not only about people flow but it's also about flow of these equipment." (Interviewee 1)

"RTLs of course, can also help in Wayfinding. So, like, not only for like these use cases we discussed previously, but also for patients, so they know exactly where to go where is a certain room or even where is a certain doctor and where are they located in the hospital itself" (Interviewee 3).

To summarize, it is seen that RTLS is used in hospitals, for instance, to locate assets, patients, and staff, to prevent theft and to prevent people from going missing as well as to optimize asset and people flow inside hospital buildings.

Interviewee 3 highlighted their views on where the adoption of RTLS shows the most promise: "*I would say the first movers are first of all hospitals and hospitals in countries with higher labor cost. Because when you look at the business case, it's mainly about*

productivity. When you have low labor costs, that productivity might not be as an important KPI as in countries with a high labor constraint…. I've seen a lot of these implementations in hospitals in Europe. And now Asia is jumping on the train as well. For example, Singapore"

Another smart healthcare solution that is seen to be emerging in hospitals is smart lighting:

"*When you put a patient in the hospital, you want him to heal as soon as possible. And lighting has a significant impact on that. So, you use so-called Smart Lighting Control. So, meaning that the lighting turns on and off based on occupancy, or the lighting could change color to a more orange-red color in the evening or blue light during the day and improve the healing process in a hospital. And it is becoming so that this lighting is becoming kind of automated, so that automatically changes based on the time of the day, but also real-time light natural light coming in from let's say a window, or the ceiling or whatever. So, these sensors they have an ambient light sensor capability"* (Interviewee 3).

According to the interviewee smart lighting can thus be used to accelerate patient throughput in hospitals and save energy costs. Another interesting mention that was highlighted by interviewee 3 is that smart lighting can have other beneficial use cases: "*Often the smart lighting control sensors have the capability to also enable real-time space utilization analytics. So, you also can create kind of heat maps, you can identify bottlenecks…But usually, when you have a large retrofit in the hospital, meaning you retrofit the lighting, you can also benefit from real-time location services and space utilization analytics. Like the sensors usually have several capabilities like six seven capabilities so they can enable all of those."* The interviewee is referring to smart lighting systems that have motion-sensing capabilities. When these smart lighting systems transmit data hospitals can get insights into how spaces are used as well as detect whether a patient is in a room or not. It was also highlighted by interviewee 3 that based on the benefits of RTLS and smart lighting these solutions will be scaled much more in the coming 3-5 years in the hospital sector.

Another technology trend that was identified in the hospital environment is robots:

"AGV stands for automatic or automated guided vehicles. You'll find a lot of them nowadays" (Interviewee 6).

"Robotics. Hospitals at least when you compare it with other building types, is going to be the first one to adopt together with probably hospitality. So, in hospitals robots will replace

humans eventually and replace human tasks. So everywhere where you have like, easy human tasks, a robot will come into place" (Interviewee 3).

"Same robots used in factory floors are usually used in hospitals. Hospitals have other kind of robots as well, such as robots that allow two-way communication with a doctor. Robots that are the same height as a human" (Interviewee 1).

"...every year more people are interested. The interest has grown especially during the pandemic. And to add to the pain points in hospitals one is social distancing, so the robot can help eliminate social contact" (Interviewee 4).

Existing use cases for robots were brought up by the interviewees:

"... there are little bots that roam around the hall that pick up food linen, dirty utility, and transport them over to their end destination" (Interviewee 6).

"So, in hospitals, it's mainly about cleaning or sanitizing also due to Covid. There have been different technologies to clean the air like via UV light or ionization and robots. To deliver things in hospitals, or to move things from one place to the other. For reception tasks, or for simple security tasks robots will be deployed" (Interviewee 3).

"So, the robots doing that kind of jobs means that the staff can focus on more valuable work, working with the clients. The workers will feel more fulfilled and get job satisfaction. And it's not just for the robots to be pushing the trolley but you can actually implement more automation for the robots. The robots can handle transportation and traceability, for example transporting the medicine in the robot's compartment and then the nurse can make sure that it is the right medicine that is going to the patient" (Interviewee 4).

To summarize, the interviewees highlighted how robots are being used in hospitals, however, it is estimated that the demand for robots in hospitals will increase. The increased adoption during the past few years is seen to be due to Covid-19. However, it was estimated that while the negative impacts of the pandemic on hospitals have eased, the adoption of delivery robots will continue. This is due to their ability to handle tasks on behalf of humans, and this can support hospitals with labor shortages.

Interviewees highlighted telemedicine as another trend. A quote from interviewee 1 explains some of the reasonings behind the increased adoption of telemedicine technologies: "*In hospitals, there's a remote trend. Hospitals are like factories, so they want the throughput*

to be fast. The patient comes in and is taken care of and goes home. They want that to be as fast as possible. So, then you have to have this kind of remote monitoring solution. So, for example, if you go for an operation in the hospital and the operation is done once and you may have to stay like overnight there. But they want to send you home as fast as possible to recuperate at home. So, then they will have this kind of remote monitoring services to monitor yourself while you're still at home not in the hospital anymore." To summarize telemedicine can be seen to relieve some of the pressures faced by hospitals today: lack of resources and high demand.

Another trend that has been emerging in the hospital environment due to the pandemic is seen to be contactless solutions that minimize touching of surfaces and therefore increase hygiene and cleanliness. This was highlighted by Interviewee 3: *"...especially in hospitals is touchless buildings. So, this is definitely important. Again, mainly due to Covid I would say what was already important before, so that you don't need to touch anything physically, in the building itself. So, you can request an elevator touchless. You go through access control or visitor management touchless you can change the lighting touchless right, via advocate or via voice control. Alexa, for example. You change the temperature of the room, touchless, you adjust the shading, touchless. So, it's again about the control of your environment where the trend is clearly touchless. And the other trend that goes into that is giving more power to the building users. So, the patients can actually control their environment, however they want it to be."* Another trend highlighted in this citation is giving patients more control over their environment.

Real-Time Health Systems (RTHS) was mentioned by Interviewee 6: *"I believe that real-time health system solutions will be the next largest trend. This is largely in part due to their foundational nature; RTHS augment existing investments for legacy and new builds while future proofing new technology and solutions. The data that RTHS provide will be invaluable for AI and ML solutions and provide a degree of accuracy that historic time delayed information simply cannot provide. RTHS will provide the moment-to-moment nuances that are unique to healthcare alone."*.

To provide further context as to how RTHS systems practically benefit hospitals Interviewee 6 mentions Digital Twins, which are a form of a real-time health system. Interviewee 6 also refers to Gartner's Hype Cycle in which it is estimated that RTHS Digital Twins will gain mainstream adoption in the next ten years. This was also discussed in chapter 2.1.2.

Interviewee 6 mentions RTHS Digital Twins to be a solution for the healthcare industry's challenges:*" So what we have at the core and heart of everything is an integration engine and interoperability where we are able to connect disparate systems together. This spans much further than just clinical systems. We are able to communicate to anything that speaks over IP. So, you think of IoT, you think of sensors, devices, you think of systems.".*

When asked about the type of systems and data points that are connected to a Digital Twin today, Interviewee 6 stated: "*So one of the most common clinical systems you'll hear is the EMR the patient chart. Another one might be the registration and admit discharge transfer system…then the most other common one is something like nurse call, you know where you're at the bedside, you're pressing the red button, and then the nurse call event comes on. From the building side there are many different building elements... HVAC, lighting, elevator services, security. Nowadays, a lot of blind and shade control. And of course, energy. So, the ability to adjust parameters to maximize the output of the facility."* What can be concluded based on this response is that hospitals today are using so-called smart technologies such as the previously mentioned: HVAC, lighting, blind and shade control. The interviewee also mentioned smart window technology as one element that today's hospitals have integrated with a digital twin.

When asked about specific use cases that a digital twin can enable when integrated with different data points, interviewee 6 mentioned: "*So let's say a patient is having a code blue. And you want your code response team to get to that patient's bedside as quickly as humanly possible. In our applications, we're not only able to show them where the code is happening, specifically sending a notification to the code Response Team. We can actually wayfind them to that location…Now when you think of elevators though, because all these code responders might be on different floors, we can interact with the elevator system to now perhaps preset the location of the elevator to where most of the code responders are or the closest code responders are."*

Interviewee 6 also mentioned that integrating these systems into a digital twin allows both control and automation: *"Let's say you're in a meeting room, the sun is setting. The sunlight is beaming through the window now and it's starting to get really hot. With that rise in temperature and the detection of that sunlight. The platform can automatically talk to the BMS, the building management system to say, put the shades down. So that's an example of a very simplified automated rule, where you don't need a user to press the remote control to*

lower the shades. It automatically does that." In this example temperature systems are used together with blind control systems to regulate room temperature automatically.

Interviewee 6 also elaborated that with the help of technologies such as AI and ML digital twins can be used to make context-based decisions. Interviewee 6 mentioned some examples of the capabilities that a digital twin has in terms of contextual automation by referring to the previous example of rising temperature in a room. These examples are as follows:

- A digital twin can utilize a set of rules: when a room is occupied the AC is switched on and blinds will be lowered and if the room is unoccupied the AC will not be turned on to save energy costs unless a certain temperature threshold is passed.
- When a room is occupied, the temperature will be adjusted based on individual preferences with the help of data gathered from multiple systems such as room booking systems to identify who is occupying a room, occupancy sensors, and temperature preferences saved in a BMS system

What will a technologically advanced hospital of the future look like?

The interviewees were asked to describe what in their opinion would be the most advanced hospital. Below are some citations from the interviewees:

"…a lot of people are thinking oh you're just going to have this big robotic facility that has all these cameras everywhere and robots roaming around the hospitals. I don't think that's going to be the case. Healthcare is already a laggard industry to begin with. It's one of the slowest in terms of technology adoption and everything…I guarantee you right now, today you can go into two hospitals near you, and you'll still find paper and pens all over the place… It's going to be maybe another 20-30 years before they get rid of paper" (Interviewee 6).

"I believe that in the future hospitals will minimize a lot of paperwork and replace these traditional paper-filling tasks with the help of apps, for instance. Additionally, people will do less of these transportation tasks. So, transportation of linen and meals for example will be handled by something even more advanced than for example mobile robots" (Interviewee 4).

"In the future, a hospital will have a digital twin so that different scenarios can be modeled and optimized before any changes are made to the hospital's infrastructure. Sensors will be

used to monitor the patient's recovery after a procedure. We could monitor response using the data we get from the sensors monitoring vital signs. Just like today, we have these smart watches and rings, these will be more advanced in the future" (Interviewee 5).

Interviewee 5 also emphasized how in the future equipment providers will be expected to provide a digital twin of their product, and specifications for equipment will no longer be enough. Interviewee 5 also highlighted more advanced uses for a digital twin in the future: *"Probably in the future, there will be more automation of different scenarios. For instance, during a fire, we could simulate how the doors close, or if theirs is a virus in the hospital, a room could be isolated in terms of air circulation so that the virus won't spread anywhere else"*. Characteristics of a pandemic/epidemic ward could also be achieved with the ability to isolate air circulation in specific areas in case structurally isolated wards have not been designed as part of the hospital.

Interviewee 6 emphasized interoperability and how data should be accessible, additionally they mentioned how there's still plenty of opportunities for workflow optimization. The future's advanced hospital will minimize routine work and hospital staff will be able to work on tasks that are more meaningful to their profession:*" I think the most advanced hospital in the future is one where all the data is free flowing. Anybody that needs their information, they can get it within seconds. And they know exactly what to do with it…There are still large opportunities to optimize all the workflows in hospitals… The main goal would be to get it so that all the people you have can operate at the top of their license or top of their credential. So, for a nurse, that means get it so that they're at the patient bedside more. Get it so that they're not spending all their time just typing documenting notes at the nursing station, get it so that your facilities people, they're not routinely walking around looking for degradation…Solutions that will continue to pick up traction and pave the way for the future of healthcare will be solutions that do not take away the 'critical thinking and decision making' of clinicians, however, aim to inform them with all the information they require to take action".*

3.2.1 Hospital section summary

Section 3.2 presents the pain points and challenges that hospitals are facing, based on interviews with industry experts. The biggest challenge highlighted by the interviewees is staffing and resource shortages, which are affecting the day-to-day operations and efficiency of hospitals. Clinicians are also performing tasks that could be automated or eliminated, such as pushing trolleys and searching for medical equipment. Additionally, the lack of visibility into the location of hospital equipment is affecting equipment utilization rates and making hospitals vulnerable to theft.

The traditional hospital building design with its long hallways was seen to affect negatively on the efficiency of people flow. Unexpected equipment shutdown was also seen as a pain point. Inefficiencies in people and asset flow within hospitals can affect workflow efficiency and ultimately patient care. Delays in clinical workflows, particularly during code events, can have a significant downstream impact on patients. Additionally, the proliferation of healthcare technology over the last 10-20 years has created an ecosystem full of disparate and single-purpose solutions, making interoperability a challenge. It was seen that the adoption of IoT technologies has further increased this disparity.

The hospital technology landscape is transforming, with an increase in smart healthcare technologies, such as the Internet of Medical Things (IoMT), sensors, and remote monitoring solutions. Real-time location systems (RTLS) are also emerging, enabling hospitals to track assets, patients, and staff, prevent theft and optimize the flow of equipment and people within hospitals. Additionally, smart lighting is seen as a useful technology for improving patient throughput and saving energy costs, while also providing real-time space utilization analytics. Robots are another technology trend in the hospital environment, being used for tasks such as communication with doctors, eliminating social contact during the pandemic, and logistics. The interviewees highlight telemedicine as a trend. Telemedicine relieves the pressures faced by hospitals because of a lack of resources and high demand. Another trend that has emerged due to the pandemic is contactless solutions that minimize touching of surfaces and to increase hygiene and cleanliness.

Real-Time Health System (RTHS) Digital Twins was also mentioned as a foundational trend that will be used to overcome traditionally time-delayed information sharing. RTHS Digital Twins can be used to connect disparate systems, including clinical and building systems.

Digital twins can enable a multitude of use cases relating to workflow efficiency, wayfinding, energy control, security, and safety. Digital Twins are used to provide control but more importantly contextual automation.

The chapter explores what the most technologically advanced hospital of the future would look like according to several interviewees. The interviewees predict that hospitals will minimize paperwork and replace traditional paper-filling tasks with the help of technology. Another interviewee suggests that hospitals will have a digital twin that can model and optimize different scenarios before any changes are made to the hospital's infrastructure. It is also anticipated that equipment providers will be expected to provide a digital twin of their products in the future to be embedded with the building's digital twin.

The interviewees also emphasize interoperability and how data should be accessible in real time to those who need it. In the future, hospitals will minimize routine work and hospital staff will be able to work on tasks that are more meaningful to their profession. Solutions that do not take away critical thinking and decision-making of healthcare staff, but rather inform them with all the information they require to take action will be important for the future of healthcare.

3.3 Findings – Hotels

What pain points and challenges are hotels facing?

Many challenges and pain points were brought up by the interviewees. One is labor challenges. It was emphasized by interviewee 8 as being the biggest challenge in the hospitality industry: *"So, the number one challenge that they (hotels) have is labor right now. Hiring staff, retaining staff, training staff…… Many after they got laid off, found other work somewhere else outside of the hospitality industry."*

During Covid-19 many hoteliers had to lay off employees to save costs while trying to deliver the same levels of service. To this day, hoteliers are struggling with staff shortages while travel levels have nearly reached pre-pandemic levels. This was covered in chapter 2.2.1.

Profitability challenges were also mentioned as a challenge that was accelerated due to Covid-19: *"When we went through the pandemic, most of the hotels were under-occupied.*

…. when we went through the pandemic a lot of our hotel customers small and big called us and said can you give us a discount…. can you do something so that we pay you less because we don't have customers? …The hotels were paying a fixed amount and suddenly they have less usage" (Interviewee 2).

According to interviewee 8 inner city hotels were struggling more than those in resort areas due to the amenities they provided*" …Many of them exceeded pre-pandemic level revenues. And because people wanted to go there, they may not have had high occupancy levels, but their ADR (Average Daily Rate) was very good"* (Interviewee 8).

However, while some of the hotels in resort areas had high demand, they still struggled due to limited staff. *"It's a lot of pressure, you know, working in a hotel when you're understaffed, and you've got customers coming in, guests coming in expect the same level of service as if you were when you were fully staffed"* (Interviewee 8).

Additionally, what is seen as a challenge is how hotels operate in silos both from a solutions perspective as well as from the property perspective: *"I think that the hotels are still suffering from operating in silos. And it's not just the notion of the solutions that they use are siloed, but that they will want to make decisions that are at the property level"* (Interviewee 9).

Hotels are using various systems across the property for different tasks, however traditionally these systems are not communicating with each other and not sharing data: *"So, if I go to the spa, I have a profile of the spa system and then I go to the restaurant and I eat dinner that's information in another system. And the PMS holds my reservation information. Marketing is done in another system. So, they don't all talk and it's an industry-wide issue. It's not just specific to hospitality"* (Interviewee 7).

It was also seen that system integrations are time-consuming and complicated and require many considerations.

The lack of integration and interoperability of systems can be identified to be one of the root causes for other challenges faced by hoteliers, for instance, not having a complete picture of your guests in a hotel. It was further emphasized that: *"the majority of the larger hotel organizations for the last five or eight years have all been chasing and trying to figure out how to put together the Single Guest Profile"* (Interviewee 7).

What can also be recognized as being a challenge either stemming from lack of integration, lack of technology, or lack of insight on guest behavior or all the above, is not having property-level visibility and analytics to drive decision-making: *"…they (hoteliers) don't really know if they are used (amenities), how much they are used, how many people are using it, where do people actually move from one place to the other. Where shall we add certain promotions based on the traffic of people, how much food do we need to prepare. How many people usually eat in the restaurant or have a drink at the bar. How much do we need to invest in the pool if only maybe 10 out of 100 guests use it"* (Interviewee 3).

This is further enforced by one interviewee mentioning how the lack of information is hindering personalization*." The hotels interestingly, a lot of them they don't know what's happening in their own hotels… And that is starting to bite them because they can't get into a world of personalization if you're not tracking the actual experience"* (Interviewee 9).

From the guest's perspective a challenge that was mentioned was lack of automation. It is seen that the hotel sector is lagging other sectors in terms of automation and hotels have not been able to deliver the level of automation that is visible, for instance, with other parts of the travel journey.

What trends and technologies are emerging in the hotel-built environment?

When asked about the trends and technologies in the hotel sector the following statements were made:

"I'm a big believer that hotels will go through a big transformation. The big trend that is happening today is modernization. Nobody wants to go to old hotels anymore" (Interviewee 2).

"Hospitality has been slow to adopt new technology that's changing now" (Interviewee 7).

Increased technology adoption has become more visible due to Covid-19 as stated by Interviewee 8: *"Yeah, for sure. There's demand…what a lot of some of the savvier hoteliers did was they invested in technology during a quiet time with Covid that gave them an opportunity to rethink, you know, maybe I've had a legacy system for 20 years …Let's rethink how we do things and try something different. And something different typically parlays into, giving my team as hoteliers tools that they can use or, putting more guest technology out there that guests can do a lot of that too"*. The interviewees also emphasized how hotels are

increasingly seeing technology as a means for tackling the challenges resulting from staffing shortages.

As stated previously in the challenges and pain points section the lack of system interoperability was highlighted. One of the interviewees is a co-founder of a company that tackles this issue: *"And that was the point in building our company, I wanted to be able to take the information that is siloed in different systems and expose it so that the hotels can market to the customer"* (Interviewee 9).

API's and cloud-based systems are also seen as growing trends in the hotel sector. These trends can be seen as enablers for system integration. Interviewee 7 represents a company that's core business is to help hotel management companies create a Single Guest Profile, explained also in section 2.2.1. The profile gives hotel companies access to data that is derived from various hotel systems and allows them to learn more about their guests, better serve them and drive the buying pattern through targeted marketing.

The same interviewee also listed some of the systems from which guest data is retrieved and used to create a guest profile: Property Management Systems, restaurant systems, survey and reputation management, loyalty program data, spa & golf systems, work automation systems, mobile applications, Wi Fi systems, and marketing systems. These systems also give a view into the types of systems used in hotels today.

One of the examples provided by the interviewee demonstrates how guest data from restaurant systems is used to better market to the guests:*" We may learn that you went to the restaurant, and we can read your check details and know that you've ordered 10 bottles of red wine. We'll start to learn that the guest has an affinity to red wine, or an affinity to coming in the summer or the fall and start to tailor programs based on those choices…And then if you can do that, in the long run, you're creating a better experience and it's much easier to retain guests than it is to find new ones. You just create more value, make them want to come back over and over again"* (Interviewee 7).

When asked about other trends Interviewee 8 stated: *"I think it's just overall doing more with less, less staff"* (Interviewee 8). This statement can be seen to correlate with a growing trend in the industry which is automation and self-service to tackle staff shortages.

Another identified reason for increased demand for automation aside from staffing shortages were seen to be Covid-19 related to hygiene and cleanliness challenges that created demands

for contactless solutions that enable guests to self-service. The interviewees mentioned, for instance, contactless check-in and check-out through mobile, digital room keys, robots, and contactless control of the hotel rooms' environment.

Interviewee 8 stated that hotels are looking at check-in and check-out kiosks for guests, but more hoteliers are leaning towards utilizing guests' mobile devices: *"There are some hoteliers interested in looking at kiosks so you could get to the hotel and check in that way as well. But I think more of it is leans towards mobile, because you always have your phone near you. So, you don't have to go somewhere find something but it's in your hand and you can control your journey and that's I think that's a win for guests and hotels."*

While the guest journey is expected to become more digital comments made by the interviewees emphasized that hotels should also give their guests a choice over the use of technology as many are not tech-savvy or prefer human-to-human interaction: *"I think the industry expects that we give them choice for their guests that their guests. If they're technology savvy let them use their mobile devices and if they want to check in online, go right to their room, get into the room through a door lock electronically through their phone. They can do that, or the guests may have a choice that they can check in traditionally."* (Interviewee 8)

The interviewees highlighted personalization as one trend. As seen in the previous statements advanced personalization is enabled today with technology and its integration, for instance, by utilizing Single Guest Profiles to better market to guests. Guest data is also being utilized today for targeted advertisement: "*(Hotel group) started a pilot in the US for advertising which is targeted advertising so they are tracking people and are trying to target their advertising so they can track people inside the hotel. They also have data about people's behavior in the online space when they have been clicking ads or pressing. So, they can sort of identify the type of person who's coming to the hotel, and they can target advertising to their application on their mobile and the TV in the room"* (Interviewee 1).

The same hotel group has also experimented with a Proof of Concept (PoC) where flight information data was utilized to better serve the guests: *"They knew the flight was delayed, so they sent a text message automatically. Hey, would you like for us to have a sandwich ready for when you get here because the restaurant is closing"* (Interviewee 9). The

interviewee further stated that this is the level of personalization that should exist in the future today, however, system integration is still a challenge.

Through the trend of personalization, it can be naturally observed that the identification of people becomes central, the ability to better market and serve guests ties in with being able to identify who they are. This can also be identified in one of the statements: *"People identification is becoming more popular"* (Interviewee 1).

When asked about the means of identification Interviewee 1 stated:

"Access control systems are used to identify people and the data is sent to a database, this allows personalization of building experiences, for instance, directing someone to a specific floor or sending data about a person arriving, for example to the hotel reception…. Access control with key cards is the typical solution. But nowadays also biometric is coming up especially in Asia, it's more and more common. Biometric is typically face recognition for example with security cameras and they recognize faces." What can be observed from these examples given by the interview group is that nearly any technology that the guests interact with during their hotel stay is used or should be used for gathering data to enable personalization.

What was also observed is that guest messaging is becoming a popular means of communication in hotels, especially AI-powered guest messaging as it allows personalization to be automated:

"I think guest messaging is big in the hotels these days. Once you're in the hotel, you can opt in, or you can opt out, but you may want to order you know, firmer pillows in your room. You can send a message down to the front desk, where many of these requests are handled through artificial intelligence…. they'll give you an answer or say sure, we'll have somebody out in 10 minutes to provide your pillows…. So, it's communication during the guests stay that is definitely becoming a big thing too" (Interviewee 8).

"I think that the notion of which you need AI for personalization will continue…You see some of the bigger hotel groups doing some of this, where they start to create experiences curated for particular types of customers, where there is super high levels of loyalty…. They know what you like. And then when you're in that city, they can say, well, I know that you like sushi. Well, you know what I curated a list of the restaurants that we feel as a property are the best ones and that's based on employee experiences and some customers that feels

like you will enjoy probably this one the best. If you could deliver that as part of the experience, and then help to make that visit to a city better. That's the type of AI communication that will drive interest, personalization, and it drives a better experience for the customer." (Interviewee 9)

One of the interviewees also implied how data guest data could be utilized to further personalize the hotel room experience once the guest returns:*" In a hotel, when you are a frequent user of a specific hotel, the hotel room should be already personalized according to your preferences. So, the temperature, then, for example, a certain TV channel, shading or lighting or maybe a menu for the restaurant, that food that you prefer or drinks that you prefer based on your consumption in the media bar and stuff like that. There should be certain personalization especially the hospitality area."* (Interviewee 3).

It was identified that personalization can also feel intrusive to some extent for the guests, however when hotels can find the right balance personalization can create an advantage:

"We shouldn't go too far because you also don't want to feel like you're tracked everywhere" (Interviewee 3).

"This exists today, where you can track your customers. That doesn't become creepy anymore because you're helping them. You're delivering value to them… If they can make my visit to a city better, then they will be winning. And so, anything in that regard that will predict what my needs will be and try and deliver against those in a non-intrusive way. I think it's a win" (Interviewee 9).

Another emerging trend that was identified is that to some extent due to Covid-19 hotels have been more actively adopting new revenue strategies that focus on non-room revenue. Some hotels are moving away from calculating revenue based on only the rate paid by a guest for a room, but rather how much the guest is spending on top of the room rate: *"Now I think the industry is moving to a new term called TRevPar… The goal now is starting to become how do I find the right guest to spend the most money at my property?"* (Interviewee 7). TRevPar stands for total revenue per available room, and it can better capture how much revenue a guest can generate across all hotel departments.

What will a technologically advanced hotel of the future look like?

The interviewees were asked to describe what in their opinion would be the most advanced hotel. Below are some citations from the interviewees:

"if they could really limit the staffing needs to only focus on delivering hospitality, the more that you get, the more that you can make a facility that runs itself, heals itself, fixes itself, cleans itself the more lucrative it'll be for a for hotels… So essentially, if there's somebody not helping the experience, then how could you automate the tasks? And it's because you're trying to not have employees but it's because they are hard to find. And they don't want to do a lot of these jobs." (Interviewee 9)

"In the future technology needs to be used to make the guest experience better. Those who want to use the tech can, but it should not be forced upon a guest. Technology should be used to make the guest stay on property even better" (Interviewee 7).

"What I see in a few years is there will be more self-service hotels, where you don't have any staff necessarily at the hotel. So, from the way to the hotel to the entrance or check-in of the hotel, through the elevator to the floor…. Everything automated and you don't need any person to intervene" (Interviewee 3).

"…but I will say that you know what we talked about before for personalization perspective. If they can make it about, if they can make my visit to a city better, then they will be winning. And so, anything in that regard that will predict what might needs will be and try and deliver against those in a non-intrusive way. I think it's a win." (Interviewee 9)

Furthermore, it is seen that what has been for long a traditional hotel room with many different devices and technologies such as complex TV systems, telephones, and iPads will retire. In-room technology will either become less visible or live more organically. These devices will most likely be replaced by mobile devices. *"I think that you see it already. They have made very rich environments in the hotel room. In some cases, where they bring a lot of technology in, I think you'll probably see less technology in the room in the future."* (Interviewee 9)

3.3.1 Hotel section summary

The hotel industry is facing various challenges and pain points, including labor shortages and profitability challenges due to the Covid-19 pandemic. Hoteliers are struggling with staff shortages while travel levels are reaching pre-pandemic levels. Hotels are also operating in silos, with different systems across the property for different tasks that are not communicating with each other. The lack of integration and interoperability of systems leads to other challenges, such as not having a complete picture of guests and a lack of property-level visibility and analytics to drive decision-making. From the guest's perspective, pain points include low levels of automation in comparison to other parts of the travel journey.

Section 3.3 also discusses the emerging trends and technologies in the hotel-built environment as identified by several interviewees. The hotel industry is going through a transformation driven by modernization and increased adoption of new technologies, especially after the pandemic. The use of technology is viewed as a way of addressing the challenges resulting from staffing shortages. One of the growing trends is automation and self-service to tackle staff shortages, hygiene, and cleanliness challenges. Contactless solutions such as mobile check-in, digital room keys, and robots are being adopted.

The interviewees highlighted personalization as one of the trends, with Single Guest Profiles being used to better market to guests based on data gathered about guest preferences and behavior. A key enabler for guest data gathering was seen to be guest identification technologies and other guest journey touchpoint technologies. Guests' data is also being used for targeted advertising. It was also highlighted that hotels should give guests a choice over the use of technology as many are not tech-savvy or prefer human-to-human interaction.

API's and cloud-based systems are seen as growing trends in the hotel sector, enabling system integration. Lack of system interoperability remains a significant challenge, which some companies are addressing by providing solutions to integrate various hotel systems such as PMS, marketing systems, mobile applications, and even flight information systems. Ultimately, system integration is seen as a key enabler for advanced personalization and thus, better guest service. To automate personalized service and reduce the workload of staff, hotels have been adopting AI-based guest messaging. Furthermore, an additional trend exuberated by the pandemic is the shift to non-room revenue strategies, where hotels are

investing more in on-property services and other revenue-generating areas to maximize guest spending on property.

The chapter explores the opinions of various interviewees on what a technologically advanced hotel of the future would look like. The interviewees agree that automation and self-service will play a significant role in the future of hotels, where staffing needs will be limited, and technology will be used to enhance the guest experience. However, they also emphasize that technology should not be forced upon guests who do not want to use it. Personalization is also considered essential for making a guest's visit better and its role was estimated to continue growing. In-room technology is expected to become less visible, with mobile devices likely replacing, for instance, complex TV systems, telephones, and iPads.

4 Results

This chapter presents the results from the perspective of the defined research objective and research questions. This chapter combines the findings from chapters 2 and 3. Section 4.1 presents the identified trends, technologies, challenges, and pain points. In section 4.2 hypothetical visions of a hospital and hotel of the future are presented.

4.1 Trends, technologies and drivers

Tables 3 and 4 present the key emerging trend and technology themes for hospitals and hotels. Tables 3 and 4 also include a description of the trend and technology theme, a column with correlating sub-trends/technologies and challenges and pain points presented as “drivers”.

Table 3 Trends, technologies, drivers - hospitals

Trend/Technology	Description	Linking trends/technologies	Drivers
Automation	Technology that enables automation is becoming more popular e.g., robots and automated waste management systems. Hospitals are adopting robots for various use cases e.g., to handle routine tasks such as transportation of medicine and linen, to support with wayfinding, and to provide support for patients in distress especially children. Newer hospital buildings are using automated waste management systems that allow waste to be transported underground. Digital Twin technology is used to control and automate various tasks in the hospital-built environment.	Digital Twins, Robots, Automated Waste Management Systems	Robots have been adopted to support hospitals manage labor shortages, automate manual tasks, support the work of clinicians and to reduce the amount of walking needed from clinicians in large hospitals. More hospitals are adopting vacuum waste management systems to reduce the risk of contamination that comes with traditional waste transportation.
Digital Twin	Digital Twins utilizing data from various technologies and systems across the hospital facility to provide real-time situational awareness, as well as predict future states based on historic data. Digital twins enable control and contextual automation. Digital Twins have also been utilized in hospital building construction phases to simulate, for instance, air circulation efficiency. The research results indicate that Digital Twin technology will be scaling to become part of more healthcare organizations digital initiatives in the coming years.	Automation, Energy-efficiency, Interoperability, Air circulation simulation and control	Digital twin technology is seen to solve interoperability challenges, as well as increase operational efficiency by, for instance, eliminating waste (e.g., time delays) from hospital workflows. Digital twins enable hospitals to utilize all available data in real-time.
People and Asset Tracking, Wayfinding	RTLS is becoming a more popular technology being adopted in hospitals. RTLS enables real-time locating of people and assets throughout the facility. Hospitals are also using RTLS to enable, for instance, visitors and staff to find patients. Wayfinding technology is becoming more common in the hospital setting as hospitals are adopting, for instance, mobile applications for navigation guidance for both patients and staff.	Automation, RTLS	Asset management challenges such as locating equipment, people and preventing theft. Complex hospital designs and the time-sensitive nature of hospitals is creating demand for solutions to streamline wayfinding with technology.
Smart Technologies	Smart technologies such as smart lighting and windows as well as blind and temperature control are technologies being adopted in hospitals both for energy saving measures as well as to promote healing of patients and increase patient throughput. Smart lighting systems are also used as occupancy sensors and detect, for instance, whether a patient has left their room. Smart windows reduce the need for blinds and help regulate room temperature without the need of blinds. Occupancy sensors are also being used to better understand how a facility is used and to reduce energy consumption.	Energy-efficiency, Occupancy sensors, Smart lighting, Smart windows, Patients in control	Smart technologies are being adopted, for instance, to reduce energy use, increase patient throughput, and track patients.
Telemedicine	Hospitals have been adopting telemedicine more rapidly since the pandemic, for instance, to increase patient throughput. Telemedicine enables, for instance, remote monitoring of patients with IoT technology.	Remote monitoring	Resource, labor, and supply challenges during Covid-19 have increased the adoption of telemedicine technologies.

Table 4 Trends, technologies, drivers - hotels

Trend/Technology	**Description**	**Linking trends/technologies**	**Drivers**
Automation	Hotels adopting solutions that increase automation, reduce manual work of staff, improve operational efficiency, and allow guests to self-service, for instance, with the means of contactless technologies and AI-enabled chatbots. Self-service technologies are increasingly utilizing, for instance, guest mobile phones, and this is seen as a means of reducing other costs by replacing, for instance, in-room devices and traditional room keys. Hotels are using robots to automate, for instance, deliveries.	Mobile-based guest journey, Robots, AI-chatbots, Contactless technologies	Increased travel and labor shortages stemming from the wave of layoffs during Covid has made it difficult for hoteliers to deliver against demand. Hygiene and cleanliness expectations accelerated the adoption of self-service technologies to limit human-to-human interaction. Guests prefer technology-enabled hotel stays. Hotels are looking for ways to reduce costs.
Non-room revenue	Hotels are looking for ways to create additional revenue. This means that the traditional primary revenue source – room rate – is becoming less of a priority and hotels are moving towards calculating revenue based on how much a guest is spending during their stay. Hotels are investing in on-property amenities and improving their marketing efforts to drive the buying pattern, for instance, with targeted advertisement.	TRevPar, Targeted advertisement	Profitability and occupancy challenges during Covid-19 drove hotels to look for additional revenue sources.
Personalization	Personalization is a trend that aims to provide personalized service for hotel guests by utilizing guest data to learn guest preferences, wants and behavior to provide a better guest experience and retain guests. Personalization is accomplished today with increased use of in-room technologies (e.g., enabling control of room environment), hospitality systems that log guest behavior (preferences and wants), technologies that enable guest identification/detection (behavior and personalized service). Advanced hotels integrate data from hospitality systems into a centralized guest profile with the help of API's and cloud-based systems.	Interoperability, API's, Single Guest Profile, Guest detection and identification, Cloud-based systems	Increased competition in the hotel industry, need to retain guests and drive their buying pattern, as well as offer a better guest experience.
Smart technologies	Hotels are adopting more smart technologies to gather data across the building, especially in-room technologies. These technologies are used, for instance, to reduce energy consumption (occupancy sensors, smart lighting, smart windows) and to better serve hotel guests (control of in-room environment and personalization).	Guests in control, Energy-efficiency, Occupancy sensors, Smart lighting, Smart windows	Demands for energy efficiency from external stakeholders and guests as well as rising energy costs and guest expectations for personalized experiences.

Tables 3 and 4 present the key trends and technologies that were identified in the literature and empirical phases of the research. Column one presents the larger trend/technology themes, while column three depicts sub-trends/technologies of a specific theme and/or trends/technologies that were identified to be linked with a specific theme. Pain points and challenges that are correlated to a specific theme are described in the fourth column "Drivers".

In both tables it can be identified that both hospitals and hotels have their own unique trends relating to the built environment and most with their own unique use cases. However, some similarities can be observed. For instance, both tables have the automation category, with the linking trend also being robots in both. Automation is being used, for instance, to tackle employee shortages both in hospital and hotel sectors, where robots are used to handle deliveries.

The smart technology category is also appearing in both tables together with the linking trends: energy-efficiency, patients and guests in control, smart lighting, smart windows, and occupancy sensors. In both hospitals and hotels, IoT is utilized in the form of occupancy sensors and smart lighting, for instance, to optimize energy consumption among other use cases, mainly relating to patient safety, hospital workflow efficiency, and improved hotel guest satisfaction through personalization. It is also worth noting that smart lighting and occupancy sensor technology are not necessarily always two separate technologies, but the sensors in the smart lighting systems can also be used to provide data about occupancy levels.

Another similarity in both building types is giving hospital patients and hotel guests more control over their environments, however, the purpose can be seen to differ slightly. In hospital environments patients are given control to make their stay as comfortable as possible with the aim of hopefully speeding up their recovery time and increase patient throughput. In hotel environments guests can similarly make their room environment as comfortable possible so that they will enjoy their experience and want to return.

With the growing amount of disparate technology and systems being adopted through different vendors interoperability challenges can be seen to affect both building types. The research indicates that Digital Twin technology will become mainstream for hospitals in the future, and it was seen that due to its integration capabilities, will also be a solution for interoperability challenges. It was identified that hotels are already using APIs and

partnering with 3rd party companies to integrate disparate hospitality systems, mainly for centralizing guest data to enable advanced personalization.

There are a few specific trends that were not directly cited as "trends" per say, however they can be interpreted as such. For instance, energy-efficiency, which can be seen to be a fundamental value proposition for many of the identified technologies such as digital twins, smart lighting, and occupancy sensors, as well as mobile guest journey, which refers to the observation through literature and interviews that hotel guests are increasingly performing tasks with their smart phone devices.

Table 5 illustrates the weight of each trend/technology in literature and in the empirical phases, based on how much a specific topic was mentioned. The table depicts this information with color-coded indications.

Table 5 Trend/technology weight in literature and empirical stages

Hospitals			**Hotels**		
Trend/technology	**Weight in:**		**Trend/technology**	**Weight in:**	
	Literature	**Interviews**		**Literature**	**Interviews**
Air circulation simulation and control			AI chatbot		
Automated Waste Management			API's		
Automation			Automation		
Digital Twin			Cloud-based systems		
Energy-efficiency			Contactless technologies		
Interoperability			Energy-efficiency		
Occupancy sensors			Guest detection and identification		
Patients in control			Guests in control		
People and asset tracking (RTLS)			Interoperability		
Robots			Mobile-based guest journey		
Smart lighting			Non-room revenue		
Smart windows			Occupancy sensors		
Telemedicine			Personalization		
Wayfinding			Single Guest profile		
			Smart lighting		
			Smart windows		
			Targeted advertisement		
			TRevPar		

Very low to none
Moderate
High

In Table 5 the trends/technologies with the highest weight both in literature and in the empirical phases for hospitals are automation, digital twin technology, interoperability, occupancy sensors, people and asset tracking and robots. Out of these, based on literature, digital twins can be identified to be the technology that is in its earliest phase of maturity – compared to the other trends which are already visible in today's-built environments. Interoperability is still seen as a challenge today. However, it can also be labeled as a trend due to the observation, that hospital environments are aspiring to remove data silos. This is also true for hotels.

In the hospital side, Table 5 demonstrates how in some cases a specific topic received more weight in the interviews than in literature or vice versa e.g., in the case of smart lighting, telemedicine and wayfinding. While this is true, there was no trend or technology that was mentioned in either literature or interviews alone.

In the hotel side of the table, the trends/technologies with the highest weight in both literature and empirical parts are automation, guests in control, mobile guest journeys and personalization. There was also inequality of weight distribution for some trends/technologies when looking at the literature and interview columns in the hotel side. These are cloud-based systems, contactless technologies, guest detection and identification, interoperability, non-room revenue, occupancy sensors, single guest profile and smart windows. Similarly, to the hospital side, no trend or technology was mentioned only in literature or interviews.

4.2 Future vision

The combination of literature and empirical findings give indications into the future state of technologically advanced hospitals and hotels. Although, the direction of how these emerging trends and technologies will evolve cannot be predicted this section presents two hypothetical visions of the future by combining some of the key findings from literature and empirical parts into a practical patient and guest journey. These illustrations were formed to support in answering the fourth research question: What will be the key features and capabilities of a technologically advanced hospital and hotel of the future?

Both illustrations have been comprised to present how a building user (hospital patient and hotel guest) will interact with the building from their arrival until their departure and what types of technologies will be deployed and for which key use cases.

Visualizing the findings as a user journey allowed them to be presented in a compact manner while demonstrating in practice what the future advanced building environment will look like. During the analysis of the results, it was also seen that most key trends and technologies and their identified key use cases can be demonstrated parallel to a patient's/guest's stay in the building. Both illustrations were created by the thesis author during the research analysis process.

4.2.1 A patient journey from the future

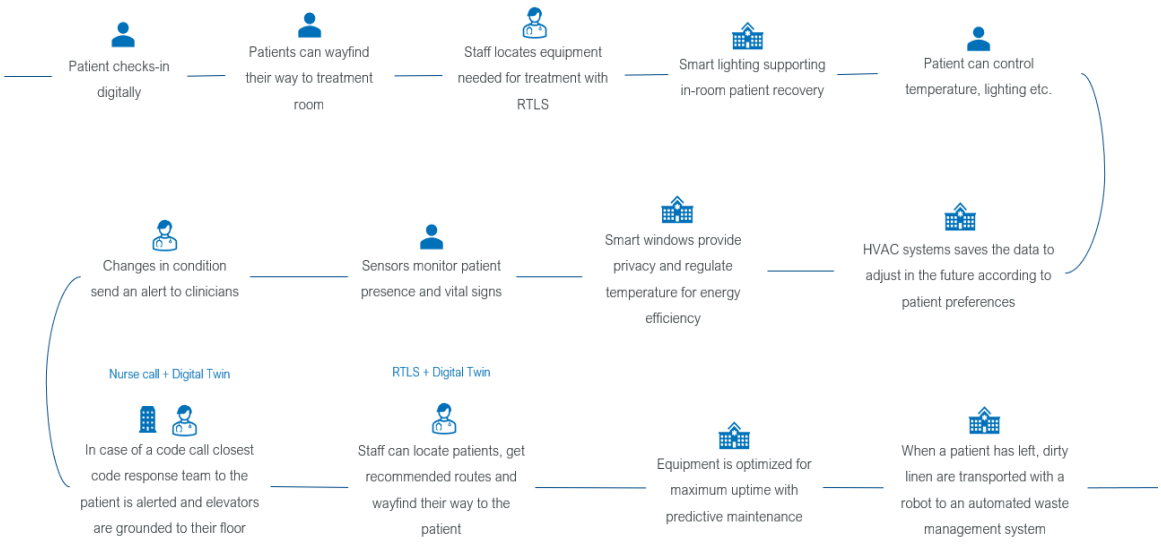

Figure 2 Future vision - a hospital patient's journey

As seen in Figure 2 the hospital of the future will use various technologies for different use cases. For instance, wayfinding technology and real-time locating systems will be utilized by both patients and staff. A patient room will be equipped with smart technologies that accelerate patient recovery, provide privacy, and increase patient throughput. A patient will also be allowed control room settings to create the most comfortable environment.

The systems used to control room settings will save the data containing the patients room preferences. These smart technologies will also enable more efficient use of energy. A

patient will be monitored with telemedicine and any changes in a patient's condition will alert the hospital staff in real-time. In case of a time-sensitive emergency, workflows will be optimized, for instance, by utilizing both the patients' and emergency response teams' location to allocate the right elevator to a specific code call. Elevators will ground to the response team's floor. This use case also demonstrates the capabilities of a Digital Twin when different systems and technologies are integrated.

Other workflows will also be optimized with people and asset locating systems to enable route optimization. This could mean, for instance, utilizing people traffic data to provide insights on fastest routes from location A to B. Equipment maintenance needs will be predictable and the uptime of critical equipment will be maximized to avoid any disturbance in hospital workflows. Once a patient has been released from the hospital a robot will transport dirty linen to an automated waste management system, thus minimizing risks of virus or bacteria contamination.

The future vision of a hospital features many technologies all of which seamlessly integrate to share data. Integration is facilitated by a digital twin that enables advanced automation, requiring minimum interference from hospital staff and allowing them to focus on meaningful tasks. Information and data are digitized as opposed to being in a paper format. Operational efficiency is maximized with automation which helps eliminate waste resulting, for instance, from delays and patients or equipment going missing.

4.2.2 A guest journey from the future

Figure 3 Future vision - a hotel guest's journey

In a hotel from the future a guest journey will rely on using guest's mobile phones. Guests would have the ability to check-in with their phones without having to wait in line in the reception. Check-in kiosks and reception staff will be minimized to save costs. However, staff will be available to check-in guests manually especially in cases where guests are not comfortable with technology or prefer human-to-human interaction.

For added personalization and attentiveness, a registered guest could be identified as they enter the premises and be given a personal greeting by the staff. Systems will be integrated with the help of API's and the data will be used to enable advanced personalization. Flight information, for instance, could be used to alert staff of guest flight delays allowing them to proactively serve guests based on perceived needs.

The systems used to control room settings will automatically start adjusting to the guests' preferences once it is detected that they have entered the premises. Thus, guest identification technologies will be used as an advantage, these could be, for instance, mobile phones, access management solutions or Wi-Fi systems. Guest data will be saved and accessible in a centralized Guest profile. Guests will have the option to go directly to their room and enter with their mobile phone's digital room key or another means of digital access management. Physical room keys will be limited to save costs and limit the need for room key management.

An AI chatbot will support with guest service requests or questions to lessen the workload of staff. AI would enable priority ranking of guest requests, to identify those with highest urgency. Service robots will autonomously move around the premises, be detected by automatic doors, and use the elevators to move across floors. Sensors will be used to streamline guest movement inside the premises, make cleaning tasks more efficient and regulate energy consumption. Elevator calls will be automatically grouped in a smart manner to ensure efficient movement of guests, especially during crowded times. Guests will have the ability to avoid the traditionally crowded reception area during check-out times and digitally check-out using their mobile phones.

The future vision of a hotel demonstrates advanced automation, where guest satisfaction is at the centre. Automation and advanced technologies will also be used to attract new employees to fill the worker shortage. With the growing amount available data on hotel guests, personalization, and the ability to predict guest needs will become more advanced making hotel guests more likely to return and become loyal customers.

As can be seen in Figures 2 and 3 the user journey's have been formed with the identified trends/technologies in mind that were also presented in Tables 3 and 4. While not all individual trends/technologies are directly visible, those that have received the most recognition in the literature and empirical findings - based on Table 5 - have been featured in the user journey illustrations.

5 Conclusions

The main objective of this study was to identify emerging trends and technologies in the built environment of hospitals and hotels. To achieve these goals qualitative data was gathered through literature research and expert interviews. Four research questions defined to support in achieving the objective, these are: what are the pain points and challenges faced by hospitals and hotels? How are these pain points and challenges being addressed through emerging trends and technologies? Which specific use cases are being catered to by these emerging trends and technologies? What will be the key features and capabilities of a technologically advanced hospital and hotel of the future?

Similar findings emerged from both the literature and interviews. The interviews, however, provided more nuanced input and validated the literature findings. The identified trends and technologies were categorized into two separate tables including main trend/technology themes for both building sectors, a column depicting linking trends, and a separate column "drivers" indicating what pain points and challenges can be seen to be the causes for the emerging trend/technology theme.

In the hospital-built environment the key trends and technologies were telemedicine, digital twin technology, automation, people and asset tracking, wayfinding, and smart technologies, with some of the key challenges and pain points facing the hospital sector being staffing shortages, lack of automation, interoperability challenges, asset management challenges and complex hospital layouts. Some of the key use cases identified were, for instance, using robots to automate logistics, using RTLS to locate assets and people in real-time and using smart sensors to improve patient recovery.

In the hotel side the key trends and technologies identified were automation, personalization, smart technologies, and non-room revenue. Some of the key challenges and pain points facing the hotel sector are staff shortages, reducing energy consumption, changing guest expectations, and profitability. All trend and technology groups were recognized to some extent in both literature and interviews. Some of the key use cases identified were, for instance, giving guests the ability to control their room environment with their mobile phone, using smart sensors to optimize energy consumption and gathering guest data to better target advertisement and drive the guest buying pattern.

Each of the emerging trends in both built environments bring up technology to the center in one way or another. Many of the pain points and challenges that were identified in this study show clear correlations to the emerging trends. For instance, the trend of wayfinding technology in hospital buildings correlates directly with the finding that existing older hospital buildings are difficult to navigate. Another example is the trend of automation in the hotel environment which correlates with the challenges of staffing shortages and guests' increased expectations for technology-driven hotel stays.

As the direction to which trends will evolve cannot be predicted, it is worth mentioning that in the future the demand for some of these technologies during the buildings operational phase could potentially decrease. This could be the result of changes in traditional ways for building design, or future-proofing a building with technology already during its construction phase. Another reason could be building modernization. For instance, the demand for wayfinding technology in hospitals might reduce if hospital layout design changes to enable more intuitive navigation when new buildings are designed or older buildings are modernized. Thus, it is important to state that most of these findings are applicable when considering existing buildings in their operational phase.

The future vision for both buildings was derived based on the identified trends and technologies and interview input, considering that each of key finding will be adopted in existing buildings in the future. The future vision was presented from the point of view of a hospital patient and a hotel guest. It aimed to present their user journey starting from their entry to the building up until their departure. Both journeys of the future utilize advanced technologies and depict how users will have more control over their environments. In both examples technology is used to provide patients and guests with an enhanced experience. Different systems, equipment and technologies are integrated. In the most technologically advanced hotel of the future improved guest service and comfort will clearly become a central element, with technology deployed to make the guests stay better. Though in the future vision technology will be beneficial for the guests, it will also be used to make the work of the hotel staff more efficient and meaningful.

What stands out as a clear theme in the most technologically advanced hospital of the future, is utilizing technology to make processes more efficient and optimized by removing waste and minimizing delays. This will benefit the work of hospital staff and improve patient care.

Facility level visibility will be maximized by utilizing real-time data, IoT and digital twin technology to provide a real-life digital representation of the hospital and all its elements.

The findings of the research raised opportunity areas for the case company and other service providers. These are discussed in more detail in chapter 5.2 with deductions made for confidentiality reasons. The biggest contribution of this study is for the case company. With the opportunity areas presented as a whole, the case company has received suggestions as to the types of new service opportunities that exist in both building types, specifically those that require partnering with other service providers. The results will be shared amongst the company's design teams, to hopefully inspire and support further innovation. The interviews with other service providers introduced the case company to potential partner candidates that will be explored further. The findings have also given the company indications into specific technical development needs that would support hospitals and hotels achieve their desired future states.

5.1 Limitations

Naturally, the results of this research are impacted by the chosen research and data gathering methods. This study focused on researching the emerging trends and technology landscape of two built environments without any specific geographical scoping. Literature was researched with a global perspective in mind. However, not all literature used in this study included geographical viewpoints.

As it was not part of the scoping to focus on geographical differences it is important to mention that these study findings cannot be concluded to cover all areas globally, nor does their maturity equally distribute. Thus, the results cannot be deemed as equally universal, and this ultimately impacts the reliability and validity of these findings to some extent. However, it is recommended that further research is applied to grasp area and country level differences if needed.

In this research it was chosen to interview individuals from companies that offer products and services to the chosen segments. The company and expert insights were gathered from companies that operate in two or more continents and the experts who eventually were

interviewed did have global level perspectives. With this interviewee selection method, findings that cover limited areas were avoided.

As it was difficult to find interviewees that have expertise with both hospitals and hotels, the number of interviews was divided equally among the two. This limited the extent to which insights could be gathered. However, while the number of expert interviewees was limited, the literature review substantially validated the literature phase findings, as several expert opinions were confirmed in the literature phase as presented in section 4.1. This implies that most of the interview results can be deemed as valid and reliable due to the overlap in literature. Thus, it is recommended that the literature findings are not overlooked.

Additionally, it is important to mention that when conducting interviews, interviewees usually have different levels of expertise and bias based on their experience. Time constraints also affect the outcome as there might not be enough to cover every aspect thoroughly. Thus, this research might not cover all relevant trends and technologies.

The schedule and scope of this study limited the depth of the analysis. For greater benefits to the case company, further analysis and data gathering would have been necessary to derive even more opportunity areas, detail and implications. However, this study has given a basis for further research. The next section proposes next steps for the case company and other service providers.

5.2 Opportunity areas

This chapter analyzes opportunity areas for service providers in hospital- and hotel-built environments based on the research findings. For confidentiality reasons, the opportunity areas and implications for the case company are not included in this thesis.

In general, it can be concluded that opportunities lie in the context of the identified pain points, challenges, trends, and technologies presented in chapter 4. The future visions for both building types also give possible indications as to the direction the hospital- and hotel-built environments are headed towards and the types of demands that are and will be emerging. However, special emphasis can be placed on a few factors.

In hospitals operational efficiency and patient care are essential. It was identified that today there’s still plenty of opportunities to optimize these aspects. Key areas that impact

negatively on operational efficiency and patient care are delays in processes, lack of visibility into the location of people and assets, unexpected equipment failure and complex hospital structures. The hospital vision of the future presented some use cases for improving these areas; however, most rely on certain technologies to be deployed and their interoperability amongst each other. According to the research the technology landscape of hospitals is quite fragmented and that there is a need to find the means for system orchestration. For service providers developing new in-house systems to work together with existing ones or partnering with other service providers could be beneficial. It is also estimated that due to the capabilities of digital twin technology, its adoption rates will increase in the future and create opportunities for hospital system vendors to integrate with other systems more seamlessly.

A big theme in the hotel sector is personalization and the research shows that it will become more advanced in the future. Some hotels are already using centralized guest profiles where guest data form different hospitality systems are integrated. However, to some extent, interoperability is still lacking. Personalization also overlaps with the trend where hotels are aiming to generate more non-room revenue as better personalization can translate to improved marketing and increased revenue. Thus, an estimate is that service opportunities lie in allowing hotels access to siloed guest data and utilizing hotel guest journey touchpoint technologies and systems more effectively to learn more about guests.

5.3 Proposed next steps

This study focused on finding out answers the question: what trends and technologies are emerging, why these trends and technologies are emerging by examining the challenges and pain points and how will the hospital and hotel-built environment transform in the future based on these findings. Even though, implications and opportunity areas were derived from the results, the results of this study could be refined further.

Therefore, as next steps it is proposed that the findings from these interviews be utilized in further research in the case company. Similarly, any other companies that act as service or technology providers for the hospital and hotel building sectors could utilize the study results to discover how these results could impact their business.

First, it is recommended that the case company works on identifying opportunities for service and technical improvements based on the study results. Next these opportunities could be validated with existing customers and/or partners and development needs could be prioritized accordingly. The case company could also consider the potential for new partnerships and service offerings.

For other service providers it is recommended that the trends and technologies are considered from the company's standpoint. This would mean, for instance, answering questions like: how is this trend/technology relevant to the company? Is this trend/technology an opportunity or a threat for the company? What opportunities will arise from the trend/technology? How can the company meet the needs that the trend/technology is creating? Which types of products/solutions could the company provide to meet the desires of the industry/customers/consumers? What is the business potential to create this new product or solution?

Additionally, there are plenty of available literature around the topic of trend management, detailing how trends could be translated into innovation opportunities, as well as practical frameworks and tools for assessing the relevance of trends for a company. Some of these are, for instance, trend rating, trend mapping, trend radars and consumer trend canvas. These tools could help companies consider things such as trend maturity, impact, relevance, and innovation potential. (Durst & Durst, 2017) A systematic approach utilizing the trend management methods could be beneficial in deriving new business models as well as product and service opportunities from the study findings.

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Appendix 1. Interview questions

I. Introductory

1. What is your role and responsibility area?

2. What kind of solutions does company XX provide to the hospital/hotel sector? (External question)

II. Trends, technologies, and paint points

1. What pain points/challenges have you identified relating to the hospital-/hotel-built environments?

2. Based on your experience, what emerging trends and technologies can you identify in the hospital/hotel-built environment?

3. Which pain points/challenges are these trends/technologies catering to/trying to solve?

4. What use cases do these trends/technologies enable?

5. What does the most technologically advanced hospital/hotel of the future look like in your opinion?

Appendix 2. Key concepts and terminology

Internet of Things (IoT)

IoT is defined as a network of physical objects that can communicate, sense, and share information over Internet Protocols (IP) networks. These objects, which are interconnected allow data collection and analysis for intelligent management, planning and decision making. IoT objects can be devices of all types and sizes such as, smart phones, industrial systems, home appliances and buildings. (Keyur K, et al., 2016)

Virtual Reality (VR)

VR is generally defined as a virtual object in a virtual environment, it is an artificial recreation, or a simulation of a real-life situation or environment created by a computer. Its user experiences a simulated reality primarily through the stimulation of their hearing and vision. Virtual environments can be navigated and possibly interacted with while simulating the users' senses. (Rebbani, et al., 2021)

Artificial Intelligence (AI)

AI is a topic that, in its most basic form, combines large datasets and computer science to facilitate problem-solving. It includes the sub-domains of machine learning (ML) and deep learning (DL) which are commonly addressed together with AI. These domains use AI algorithms to build expert systems that can categorize data and make predictions based on input data. (IBM, 2020)

Radio Frequency Identification (RFID)

As the name implies, RFID technology is a way of wirelessly sending data between a transceiver and a transponder. A transceiver is a tag that can be attached to various objects and used to automatically identify each object for several industrial use cases. This technology allows the identification of any object virtually in real-time. (Shields, et al., 2015)

Real-time Locating Systems (RTLS)

RTLS are commonly referred to as local systems used to identify and track the locations of assets, people and/or other objects in real or nearly live. RTLS uses location sensors to locate tagged objects inside an indoor or outdoor space or building by receiving wireless signals from tags of ID badges attached to the respective objects or people. (Boulos & Berry, 2012)

Digital Twin (DT)

A Digital Twin is defined as a digital representation of a real-life system or entity. Digital Twins act as bridge between a physical and a digital world by collecting data from various connected physical sensors and endpoints. The collected data is used to create a digital duplicate of the real-world item and the Digital Twin enables the physical item to be analysed, optimized, and manipulated. (IBM, 2022a)

Real-time Health System (RTHS)

RTHS refers to healthcare organisations where stakeholders share, adapt, and use medical knowledge in real-time. The RTHS value proposition states that clinical care can be enhanced, workflows sped up, business procedures simplified, and resources balanced better if data can be analysed and access quickly. The RTHS is distinguished by curated, thorough clinical data that is collected and distributed among all healthcare stakeholders in real time to the patient record and the decision-makers who can as a result provide informed treatment. (Krohn, 2020)

Electronic Health Record (EHR)

An Electronic Health Record is an electronic record where patient health information is stored. Its information is generated from care delivery settings, and it holds information such as laboratory data, medications, problems, and past medical history. A healthcare organization is responsible for maintaining, developing, and owning a patient's EHR and it can only be accesses by healthcare providers directly involved in the patient's care. The information in an EHR has formerly been stored in a paper chart format. (Seymour & Frantsvog, 2014)

Electronic Medical Records (EMR)

Electronic medical records are the digital equivalent of paper records, or charts at a clinician's office. EMRs typically contain general information on a patient such as medical and treatment history. (USH Health, 2017)

Nurse Call System

Nurse call systems are used to notify nurses and other medical personnel when a patient requires their attention. Nurse call systems are often located in patient rooms and other areas

where patients could need assistance in healthcare settings. The computer system sends a notification to the nursing staff when it is triggered, including details about the room where someone has requested assistance. (Kaleiv, 2021)

Building management system (BMS)

A Building Management System is a system that allows monitoring and controlling of the electrical equipment in a building such as energy, fire systems, lighting, security systems and ventilation. Its elements consist of software and hardware. A BMS is critical for regulating energy consumption in a cost-effective manner. It enables building owners and landlords to lower energy expenses and give the highest level of comfort for visitors, tenants, and residents. It enables remote control of heating, ventilation, and air conditioning (HVAC), saving maintenance employees time traveling to each building or room to turn off, turn on, or change temperature levels or air conditioning. (BMS Controls, 2022)

Property Management System (PMS)

A property management system is a piece of software used to manage various enterprises, particularly those in the hospitality sector (Adaramola, 2021). A PMS is used in a hotel setting for tasks like making reservations, managing availability and occupancy, checking guests in and out, and creating reports. This program is used internally (at a single hotel) to manage activity on the premises. (Xotels, 2022)

Application Programming Interface (API)

An Application Programming Interface, or API allows companies to make the data and functionality of their applications available to business partners, internal company departments or external 3rd-party developers. An API allows products and services to benefit from data communicated and shared between different products and services. (IBM, 2022b)

Clinical Workflows

Workflows in the hospital setting refer to tasks that need to be carried out in a specific sequence to reach a goal. (Bauto, 2021) An example of a clinical workflow is a code blue response call where a healthcare provider alerts a response team to a patient who is in immediate danger. (Healthline, 2021)